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ABSTRACT

This book provides teacher lesson plans that are designed to help teachers of computer literacy courses make appropriate use of instructional materials. It is designed to help inservice teachers with the day-to-day challenge of assisting a wide range of students in becoming more computer literate. In addition, the book is useful for educators who want to know more about how they can help students become prepared for life in the Information Age. The focus is on problem solving in general and on the roles of computers in problem solving. Each chapter contains a rationale and overview of the corresponding chapter in the related student lessons book. The chapters also contain information on ways to coordinate the material with computer literacy courses and provide lesson plans for use as assignments. The book contains 19 lesson plans which include relevant transparencies. The book is based on the philosophy of discovery-based learning and uses journaling as an aid to learning. (Contains 47 references.) (TMK)

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Teacher Lesson Plans

ED 367 287

Problem-Solving Models for Computer Literacy

Getting Smarter at Solving Problems

IR016145

By David Moursund

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- Chairman of the Association for Computing Machinery's Elementary and Secondary School Subcommittee, 1978-1982.
- Founder, International Council for Computers in Education (ICCE), 1979. The name of this organization was changed to the International Society for Technology in Education (ISTE) in 1989 when it merged with the International Association for Computing in Education.
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David Moursund

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Overview

Introduction

Problem-Solving Models for Computer Literacy is specifically designed to be used as a supplementary text in a junior high school or secondary school computer literacy course. The Teacher Lesson Plans are specifically designed to help teachers of such computer literacy courses make appropriate use of the instructional materials.

Although this book is designed for computer literacy teachers, it is likely that many other teachers will make use of the text and the Teacher Lesson Plans. *Problem-Solving Models for Computer Literacy* can be used in a wide variety of educational settings. For example, the text might be used in a course on problem solving or as supplementary material in a social studies course. *The text has been used extensively in graduate courses for teachers.*

The material in the Teacher Lesson Plans is aimed at two distinct audiences. One audience is inservice teachers who face the day-to-day challenge of helping a wide range of students become more computer literate. The other audience is educators, both inservice and preservice, who want to know more about how we can help students become better prepared for life in the Information Age, where more and more demands are placed on people's ability to solve problems.

Underlying Assumptions Inherent to the Text

Problem-Solving Models for Computer Literacy focuses on problem solving in general and on the roles of computers in problem solving in particular. Its underlying assumptions are:

1. All students can improve their ability to solve the types of problems they encounter at school and outside of school. Almost all real-world problems are interdisciplinary and involve ideas both from formal school and from outside of school. Explicit study and practice in problem solving can improve every student's ability to solve problems.

2. Computers are a powerful aid to problem solving. However, to make effective use of a computer as an aid to problem solving, one needs to have a reasonable level of skill in problem solving and an understanding of the overall field of problem solving. The use of computers in problem solving is a subdiscipline of the entire discipline of problem solving.

There is extensive research literature to support these assumptions. At the deepest level, schools are constructed on the premise that education helps a person to get better at solving problems. Essentially every Goals of Education list mentions helping students to get better at problem solving, critical thinking, higher-order thinking skills, decision making, and other areas that can loosely be brought together under the heading "problem solving."

Organization of the Teacher Lesson Plans

There is one chapter in the Teacher Lesson Plans for each chapter in the Student Lessons for *Problem-Solving Models for Computer Literacy*. Each chapter of the Teacher Lesson Plans contains:

1. A rationale and overview of the chapter in the Student Lessons. This is a brief summary of the ideas and why they are included in the student text.

2. Ways to coordinate the material in *Problem-Solving Models for Computer Literacy* with a variety of computer literacy courses.

3. One or more lesson plans. These include black-line masters for overhead transparencies and additional activities that can be used in class as assignments or assessment activities.

General Advice to the Teacher

The chances are that you have had little formal training in problem solving. This means that the first time you use *Problem-Solving Models for Computer Literacy,* you may be both a student and a teacher. Even the second and third time you use this text, you may find that you are learning a great many new ideas. That is okay. Problem solving and the general field of teaching problem solving are well suited to a learn-by-doing approach. You are practicing solving the problem of teaching problem solving.

Problem-Solving Models for Computer Literacy is written at a junior high school reading level. If you read at a leisurely pace, perhaps 250 words per minute, you can read the entire Student Lessons in about four hours. However, many of the ideas are profound. You may have encountered some of them in your graduate studies. There are entire books on metacognition, transfer of learning, modeling, journaling, brainstorming, and other topics that are treated only briefly in *Problem-Solving Models for Computer Literacy*. Don't be mislead by how quickly you can read the entire book!

The decision to adopt and use *Problem-Solving Models for Computer Literacy* is a major decision. There are many challenging ideas in the book. It uses a guided discovery-based approach and is designed to help students become more independent and self-sufficient. It is designed to encourage them to challenge our educational system and to take more responsibility for their own learning. The book can make a major contribution to preparing students for life in our Information Age.

Computer Literacy Courses

The Teacher Lesson Plans will give you a great deal of help if you are teaching a computer literacy course. You will need to make decisions on how much student time and effort will be devoted to ideas from *Problem-Solving Models for Computer Literacy* and how much will be devoted to the more "traditional" content of the course.

As a starting point, we recommend that no more than the equivalent of one to two days per week be devoted to the material in *Problem-Solving Models for Computer Literacy*. However, we recommend that these materials should be integrated into the overall course. To the extent possible, ideas from *Problem-Solving Models for Computer Literacy* should be part of each day's work in your computer literacy course.

There are many different versions of computer literacy courses. A typical course may focus on just one of the following themes, or it may draw from several of them.

A. Generic tool approaches that focus on the use of one or more of the following general purpose tools: database, graphics, spreadsheet, telecommunications, and word processor. These tools are interdisciplinary, useful in all levels of schools, and useful both in school and outside of school.

   An alternative is to build a computer literacy course around application software that fits the needs of people in a specific applications area. Music software provides a good example, as does software for use in the graphic arts. A computer literacy course could be built around a specific piece of desktop-publishing or hypermedia software.

B. Computer programming, making use of languages such as BASIC, *HyperCard*, and Logo.

C. A critical analysis approach. Here the emphasis is on reading, talking, and writing about the history and current applications of computers, and how computers are affecting our society.

There are many definitions of computer literacy. Generally speaking, computer literacy is a blend of computer science (including computer programming), computer applications, and computers in society (including reading, writing, and talking about computers and their impact on society). This book suggests that any computer literacy instruction should have a unifying theme that centers on the idea that computers are a new and powerful aid to problem solving. Computers can be used to help solve problems in every area of human intellectual endeavor. The capabilities of computers as an aid to problem solving have a major impact on our world.

Guided Discovery-Based Learning

Problem-Solving Models for Computer Literacy contains an underlying philosophy of discovery-based learning. One reason for this is the general nature of the computer field. The computer field is changing very rapidly. The computers your students will have available in their homes and on their jobs 20 years from now will be a hundred or a thousand times more powerful than the computers they now have available in school. This means that there must be a strong focus on learning to learn and on transfer of learning. A guided discovery-based learning environment contributes greatly to learning to learn, and it facilitates transfer of learning.

Journaling

There is now substantial research to support the idea of journaling as an aid to learning. Students should read *Problem-Solving Models for Computer Literacy* with a pencil and journal readily available. They should carry on a running mental and written dialogue with themselves as they study this material. This is a key aspect of improving their critical thinking skills. Reading, writing, and thinking are very closely intertwined activities.

Having students write in a journal raises an immediate question. Who will read the journal? Is a student's journal completely private and not to be read by the teacher, fellow students, or parents? Or is it open and likely to be read by a variety of people?

A strong case can be made for either approach. You, the individual teacher, will need to set the rules for your class. You should be aware of some of the consequences of the decisions you make.

For example, suppose you decide that students are to turn in their journals once a week. Then you may feel some responsibility for reading (grading?) this writing, perhaps providing some feedback. In addition, students will be constrained in what they write. Many may not feel comfortable in displaying certain emotions, lack of understanding, or personal weaknesses.

Alternatively, suppose you decide that journals are completely private. How will you deal with the situation where one student "borrows" another student's journal and begins to read it—perhaps even out loud to the class? How will you deal with the case of a student who writes nothing or who writes nothing related to the course?

Journaling is a powerful aid to student learning. Thus, the key idea is to get students to regularly write something in their journals, even if it is only vaguely related to the course. You may decide to take the position that their journals are somewhat private and somewhat public. You may indicate to your students that journals are private; however, they will occasionally be asked to recopy or photocopy a page to turn in. At that time they can copy the page (or photocopy it) just the way it was originally written or they can rewrite it. You can make it clear that either is acceptable to you, no questions asked!

Assessment

One major barrier to teaching problem solving is our conventional approach to assessment of student progress. In most teaching situations, a teacher is required to produce an end-of-term assessment of each student. This is most often in the form of a letter or numerical grade. Sometimes this is supplemented by a brief written comment about the student. Neither approach works well in a course on problem solving.

Students vary tremendously in their innate ability to solve problems. These differences are exacerbated by culture, home and school environments, and so on. A short course on problem solving is a very brief intervention into a very long and complex life. If the main part of the course grade is to be based on skill in solving a wide range of problems, you could accurately assign grades based on tests given on the first day of class. This is because one short course will have only a modest impact on a student's overall ability to solve the wide range of problems the student encounters in life. This leads to questions of what one wants to measure (what does a grade of B mean in this course?) and how to measure it.

It is possible to construct tests on some of the material in *Problem-Solving Models for Computer Literacy*. Moreover, some of what you might test is relevant to and supportive of students learning to use key ideas in the book. For example, it is important that students increase their working oral and written vocabulary to include a number of terms in the Glossary. Thus, it is appropriate to test for vocabulary comprehension.

By and large, however, it is very difficult to adequately assess what students gain by working on the materials and ideas in *Problem-Solving Models for Computer Literacy*. Thus, we strongly recommend that you down-play conventional tests of facts and lower-order skills and instead focus on participation, involvement, and the progress students make in integrating ideas and knowledge from the course into their everyday lives. In addition, you may want to assign a number of the activities at the end of the chapters as homework and make use of this in your assessment. Some additional activities for each chapter are given in the Teacher Lesson Plans. In any event, you should focus on student progress. It should be possible for every student, no matter what his or her initial level of problem-solving skills and innate ability, to make an A in the course.

A Warning

Problem-Solving Models for Computer Literacy is designed to help students learn to challenge a number of aspects of our conventional educational system. For example, the book focuses on the following question:

> If a computer can solve or help solve a type of problem that students are studying in school, what should students learn about how to solve this type of problem?

This is a very hard question. It could well be that a substantial part of our current educational system concentrates on preparing students to do things that computers already do well and in a cost-effective manner. Certainly one can find examples in which students learn to compete with machines in areas where machines are already successful.

As students come to realize this fact, they may begin to challenge you and your teaching methods. They may begin to challenge their other teachers and the overall organization of the curriculum. This is healthy and desirable. However, many teachers do not want to be challenged in this manner. Thus, you may want to explore carefully with your students some of the proper ways to challenge the conventional curriculum and conventional teaching methodologies. Also, you may want to warn your fellow teachers that you are teaching your students to question some current educational practices.

Concluding Remarks

An earlier version of this book appeared in 1990. At that time both the 4-megabit computer memory chip and the one-million transistor, 32-bit central processing unit chip were in mass production. This represents substantial progress from the time the transistor was invented in 1947 or the initial use of integrated circuits in computers in the mid-1960s. This rapid progress is still continuing. We can expect that, by the year 2000, relatively cheap 64-megabit memory chips will be available. By the year 2000, CPU chips will be faster, more sophisticated, and powerful enough to do parallel processing. Thus, you are faced with the problem of educating your students to make appropriate use of a very rapidly changing tool.

It is very important to realize that many of the ideas underlying problem solving and the role of computers in problem solving are independent of any specific hardware or software. These ideas will still be applicable many years from now. You should stress such ideas in your teaching. Keep asking yourself, "What can I teach my students about problem solving and the role of computers in problem solving that will still be relevant 20 to 30 years in the future?" Indeed, this is a challenge!

The ideas about problem solving given in *Problem-Solving Models for Computer Literacy* are applicable to adults as well as to young students. Look for ways to use these ideas in your own teaching and in your nonprofessional life. When you make progress, share it with your students. Be a role model of a life-long learner. Model the joy of learning new things and having this knowledge be an important part of your everyday life.

Preface for Students
Overview

Note: Beginning here, there is one chapter in the Teacher Lesson Plans for each chapter (including the Preface) of the Student Lessons for Problem-Solving Models for Computer Literacy. *One or more lesson plans are given for each chapter in the Student Lessons.*

Rationale and Overview

Take a careful look at the title and subtitle of the student text. Many students have a mind set that is reflected in the following statements:

1. "I have a certain, fixed level of smartness. This doesn't change." For example, some students think of themselves as "smart" and others think of themselves as "dumb."

2. "Problem solving is something we do only in math classes."

Both of these points of view are terribly wrong. One of the major goals of a course making use of *Problem-Solving Models for Computer Literacy* is to help students acquire a more realistic understanding in these two areas. We would like students to say, feel, and believe:

1. "I am better at solving some types of problems than others. I am smart enough to get better at solving any type of problem that I care to spend time on."

2. "I regularly encounter and solve problems at home, at work, at play, and at school. Problems are everywhere. What I learn at school can help me to solve some of these problems. What I learn outside of school can help me solve some of these problems. Both types of learning are very important to me."

Research on problem solving indicates that high self-esteem and a positive attitude are aids to problem solving and that they transfer between specific subject areas. That is, as you help your students to improve their self-esteem as problem solvers, you help them become better problem solvers throughout the full range of problems they encounter at school and outside of school.

The Preface for Students is an advance organizer for the book. The way in which you introduce the book and make use of the Preface for Students will set the tone for how students use the book.

The Preface for Students is written at a seventh-grade reading level. If your students are not able to read at or above this level, the book will most likely not be suitable for their use without substantial support. Of course, you can provide them with a great deal of help. Here are a few suggestions:

1. Before assigning specific readings, provide students with an overview (an advance organizer) of what they will be reading. Engage them in a discussion of the key ideas.

2. You may want to display key ideas and/or paragraphs on the overhead and read them out loud.

3. Alternatively, for some of the textual materials you may want to have students read the material out loud and engage them in discussion as to possible meanings of what they are reading.

One of the more important goals of school is for students to learn to read with good understanding of what they read. Every teacher has a major responsibility for helping students get better at reading. In many schools, students do not receive adequate feedback on their current reading skills. It is important that you help students to recognize and understand their strengths and weaknesses as readers and to get better at reading.

Problem-Solving Models for Computer Literacy is not easy to read. It contains a number of big words and complex ideas. Be sensitive to the needs of your students. Help them increase their vocabulary and their ability to be consciously aware of these challenging ideas.

The Preface for Students introduces and briefly discusses three ideas:

1. Aids to the human mind. There are lots of mental aids, and computers are one of the newer and more powerful aids.

2. Learning how to learn. Each person is unique, and each person can learn how he or she best learns. Through study and practice, a person can get better at learning.

3. Getting better at solving problems. By study and practice, a person can get a lot better at solving the types of problems encountered both in school and outside of school.

Coordination With Computer Literacy Courses

Problem-Solving Models for Computer Literacy fits nicely into a computer literacy course that has one or more of the following focuses:

1. Computer applications.

2. Computer programming.

3. Computer awareness, including exploration of social and vocational issues.

This first lesson, based on the Preface for Students, can easily be oriented toward any one of these three types of computer literacy courses. Here are a few examples of types of questions you can explore with your class that will help relate the Preface materials to each of these types of computer literacy courses.

1. Computer applications.

   A. How does the process of learning to make use of one computer application carry over (transfer) to learning another computer application? For example, does some of the knowledge and skill gained while learning how to play a game on a computer transfer to learning how to use a word processor or some other game?

   B. In what sense is a computer application, such as a word processor, a better aid to the human mind than pencil and paper? In what sense is it worse? Is an encyclopedia on a CD-ROM more or less useful than an encyclopedia printed on paper? Do answers to these types of questions vary with the particular task to be accomplished?

Note that if you are teaching a computer literacy course that focuses primarily on computer applications, you may want to have your students study Chapter 9 of *Problem-Solving Models for Computer Literacy* reasonably early in the course. They will need some help from you since that chapter uses some vocabulary and ideas from earlier chapters.

2. Computer programming.

   A. How does learning a computer programming language relate to learning natural languages, such as Spanish, or other subjects, such as math? Why is a programming language called a "language"?

   B. Why does it take so much effort to learn computer programming? Most programming languages have relatively small vocabularies.

Note that if you are teaching a computer literacy course that focuses primarily on computer programming, you may want to have your students study Chapter 10 of *Problem-Solving Models for Computer Literacy* reasonably early in the course. They will need some help from you, since that chapter uses some vocabulary and ideas from earlier chapters.

3. Computer awareness, including exploration of social and vocational issues.

    A. Do computer aids to the human mind decrease the need for the type of learning that occurs at school?

    B. If students use computer aids to problem solving, such as a calculator or word processor, will this decrease the ability of their brains to solve problems without these aids?

    C. Are we becoming too dependent on computers? What happens if the power goes off?

    D. All things considered, is our world a better place because of computers? Have students focus on examples from their own lives and from the lives of people they know well.

Lesson Plan 1. Getting Started

Primary Goals

1. Students will understand that they live in a rapidly changing world and that they need an education that helps them adapt to such changes.

2. Students will understand that they routinely make use of aids to their minds and aids to their bodies. The computer is a mind tool.

Prerequisites

1. (General) Students need to be able to read, write, participate in class discussions, and communicate with their fellow students at a level consistent with the overall level of the course. The Preface is written at a seventh-grade reading level. This is the minimum reading level needed to be successful in reading the text.

2. (Specific) None.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - Textbooks to give to students.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students)
   - Pencil and paper.
   - Spiral-bound notebook to use as a journal. (It is okay if this is not available until the next lesson.)

Time Considerations

This lesson fits comfortably into one class period. Allow students 10-15 minutes to read the Preface and browse through the book.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary.

Other very important terms and expressions receive less specific attention. Examples from the Preface include:

aids to the human mind
computer
human mind
journal
journaling
learning to learn
problem
problem solving

One major goal of *Problem-Solving Models for Computer Literacy* is to help students increase their ability to communicate freely and easily about ideas related to problem solving. Learning the new vocabulary is essential. Emphasize activities that help your students use the new vocabulary in their talking and writing. Make sure that you use the vocabulary frequently in your discussions with your students.

Most students who use *Problem-Solving Models for Computer Literacy* will have access to a word processor and will have basic skills in using a word processor. If so, you may want to assign students the task of building their own glossaries. As they encounter terms that are boldfaced in the book and/or that are new to them, they should add them to their personal glossary. They should make up a definition that is in their own language and has meaning to them. This can be an ongoing assignment, with a printout or a disk copy to be turned in every couple of weeks.

Objectives

1. Students will participate in a whole-class brainstorming activity to list aids to the human mind and how they help in solving problems.

2. Students will introspect on how they learn; students will write notes to themselves about how they learn.

3. Students will learn about journaling and that they will need to have a journal available when they are studying from *Problem-Solving Models for Computer Literacy.*

Description

Background

Every student in your class is "smart" and is capable of getting smarter. This book defines smartness as the ability to cope with (solve) the wide variety of problem situations one encounters at home, at work, at play, at school, and elsewhere.

Perhaps the single most important idea in problem solving is building on one's own previous work and on that of others. Other people's previous work has produced reading, writing, arithmetic, television, computers, and many other aids to problem solving. It has also produced foundational knowledge in areas such as learning theory, curriculum and instructional design, brain theory, and theory of problem solving. These can all contribute to helping students get better at solving problems.

Note that each aid to problem solving creates problems. Reading, writing, and arithmetic have transformed the societies of the world. They have created the need for a formal educational system. Computers are a powerful change agent. They exacerbate the types of problems created by previous aids to the human mind.

Teaching Procedures

1. Begin by displaying Preface Overhead Transparency 1: Aids to Problem Solving. Engage students in making a list of aids that humans have developed to help them solve problems. For each aid, students are to give an example of the type of problem the aid helps solve.

   An alternative to this approach and to each whole-class discussion or brainstorming exercise is to have the activity done in groups of three or four. This type of cooperative learning and small-group approach to learning can be very effective. If you have not experimented with it, this is a good place to begin. The research supporting the educational value of cooperative learning and the use of small discussion groups is convincing.

   If the activity is done in small groups, you may want to provide each group with a large piece of butcher paper. One person becomes the recorder and writes the group's responses in large print so that the butcher paper can be posted in the front of the room for the whole class to read. This type of approach is effective, but it is somewhat slow. If you regularly use this approach on the whole-class brainstorming activities in the lesson plans, most lesson plans will take an extra day to complete.

2. Now engage students in a categorization process. The aids can be categorized in many ways, such as:

   - Easy to learn to use versus requires a lot of training in order to learn how to use.
   - Expensive versus inexpensive.
   - Aids to the mind versus aids to the physical body.
   - Creates few new problems versus creates many new problems.

3. Now focus attention only on the aids to the human mind that were listed above. For each aid listed, focus added discussion on the types of problems the aid helps to solve. For example, written musical notation is an aid that helps composers to compose music and helps preserve music and pass it on from one generation to the next. (This was especially a problem before we had recording equipment.)

4. Display Preface Overhead Transparency 2: Ways of Learning. Ask the students to think about how they learn. Give them enough time so that each class member can write down a couple of responses. Then draw on their results to make a list of how people learn.

5. Now focus attention on the idea that some ways of learning are better for certain types of problems. If you want to be a good swimmer (be good at solving the problem of swimming), you can learn a bit by reading books. But actually swimming, with a good coach providing feedback, is a better way to get to be a good swimmer.

7. Have students introspect on what they have learned by the individual written brainstorming activity and the whole-class brainstorming activity on learning. Help them to realize that they have learned something about how they and others learn. That is, they have learned about learning.

8. Introduce the idea of journaling and the need to bring a journal to class. Clearly state your policy on who gets to read the journals.

9. Hand out texts and assign the reading of the Preface. Indicate that it is okay to read ahead if they like. Display Preface Overhead Transparency 3: Organize Your Thinking. Stress the idea that research supports the value of having an advance organizer to orient one's mind toward the materials to be learned.

10. Provide closure. Get students to think about some of the important ideas that have been discussed. You may want to make use of Preface Overhead Transparency 4: Preface Summary. Each student is to decide on one idea that he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to read the Preface and get a journal for regular use in class.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.

- An atmosphere of discovery-based learning was created and maintained.
- You made frequent use of the new vocabulary and Glossary words, and you provided positive reinforcement to students using these words.
- You were satisfied with how well the class went.
- Your learned some new things about your students and/or yourself.

2. Assessment of student performance.
   - Each student was engaged; at least half of them spoke at least once.
   - Each student thought of and wrote down several ideas on how he or she learns.

Extensions and Follow-up

For homework, encourage students to think about ideas discussed in class. At the next class meeting, each student should be prepared to share one example of what he or she thought of.

Alternatively, students are to talk to at least one person about the ideas from this class meeting. Each is to be prepared to share one or two ideas of what was talked about and how the conversation proceeded.

Notes

This lesson contains several new and powerful ideas. These ideas cut across all disciplines. They are applicable both in school and outside of school. Your goal is to have students incorporate these ideas into their everyday lives. Have patience. Rome was not built in a day.

Preface Overhead Transparency 1
Aids to Problem Solving

A list of some of the aids that humans have developed to help them solve problems.

1. **Ball point pen—better than a quill pen for writing.**

2.

3.

4.

5.

6.

7.

8.

9.

10.

Preface Overhead Transparency 2
Ways of Learning

A list of some of the ways that people learn.

1. **By practicing—for example, shooting baskets.**

2.

3.

4.

5.

6.

7.

8.

9.

10.

Preface Overhead Transparency 3
Organize Your Thinking

ORGANIZE YOUR THINKING

There is a box like this at the beginning of each chapter. It contains some of the highlights of the chapter. Spend a minute or two reading and thinking about these highlights. Research says that this time will be well spent. It will help you to learn the chapter material much better.

The Preface is about:

- Aids to the human mind.
- Thinking about how you learn.
- Using computers to help you solve problems.

Preface Overhead Transparency 4
Preface Summary

PREFACE SUMMARY

There is a box like this at the end of each chapter. It contains a summary of a few of the key ideas in the chapter.

The purpose of the Preface is to get you started in thinking about what this book is about. Some key ideas include:

1. A computer is a powerful aid to the human mind. Reading, writing, and arithmetic are also powerful mind aids.

2. It is important for you to learn how you best learn.

3. By studying and practice, you can get better at problem solving.

Chapter 1. Introduction
Overview

Rationale and Overview

Problem-Solving Models for Computer Literacy has two major goals:

1. To help students get better at solving problems.

2. To help students learn some of the roles of computers as an aid to solving problems.

There is an immense literature on problem solving, critical thinking, higher-order cognitive skills, decision making, and a variety of other closely related topics. In this book we lump all these topics together under the general title of problem solving. The Bibliography at the end of the Teacher Lesson Plans gives citations for some of the current literature on problem solving.

The first two chapters of *Problem-Solving Models for Computer Literacy* make use of a student's informal, intuitive definition of "problem." It is not until Chapter 3 that a formal definition of "problem" is provided. Thus, during the time you are covering the first two chapters, you should not expect students to fully agree on what constitutes a problem. Indeed, you might want to get a debate going on whether something is or is not a problem.

It is clear that there is a wide range of problems. Some problems are much easier to solve than others. Some occur only in school, while others occur mainly outside of school. Students often come to believe that there is very little relationship between the problem-solving skills they learn in school and the skills needed to deal with nonschool problems. This helps pinpoint one aspect of the issue of transfer of learning and provides a major challenge to teachers.

A Thought Experiment

Here is an interesting "thought experiment" that helps clarify what we are trying to accomplish as we teach problem solving. Imagine that there was only a very small number of specific problems a person had to cope with in life. For example, consider the following three situations and problems:

1. Given the situation of having your clean clothes laid out for you in the morning. Get dressed.

2. Given the situation of being seated in front of a plate of food. Feed yourself.

3. Given the situation of a small number of coins sitting in front of you. Determine the total amount of money represented by these coins.

If you have raised children, you realize that it takes a great deal of training and experience to become proficient at solving these problems. Indeed, young people with certain mental and/or physical handicaps may not be able to learn to solve these problems for themselves. These problems have been carefully studied in special education settings.

In this thought experiment, suppose there were only a few hundred such problems a person would ever encounter in everyday life. Then education could consist of memorizing and internalizing how to solve each of them. A behavioristic, stimulus-response approach to education might suffice. Imagine how easy it would be to design a curriculum for this setting!

However, education is not that simple. The reason is that there are innumerable problems a person encounters. As the world changes, the nature of the problems a person might encounter also changes. This leads to a very simple model of education for problem solving.

1. Learn to solve the types of problems one frequently encounters. The goal is to get so good at solving these that little thought is required and very few errors occur.

2. Develop knowledge and skills that are useful in solving problems that one has not encountered before or that one has encountered only infrequently.

Chapter 1 focuses on the idea that all students can learn to learn (and thus get better at learning). All students can get better at solving problems. The overriding goal is to help students get better at coping with less frequently occurring problems. (If a problem occurs frequently, students learn to solve it through experience or it is already part of the regular curriculum.) Students who grow up in a "rich" problem-solving environment —that is, one in which they are surrounded by people who routinely engage in dealing with a wide range of problems—have a distinct advantage over children who do not have good opportunities to learn problem solving in this manner.

Methodology Used in This Book

The methodology used in this book is based on a careful analysis of the research on problem solving and a variety of educational research literature. It includes substantial emphasis on:

1. Acquiring and internalizing a working vocabulary that can be used to think, talk, and write about ideas related to problem solving.

2. Journaling.

3. Small-group and whole-class discussions.

4. Small-group and whole-class brainstorming.

5. Cooperative learning.

6. Metacognition.

7. Consciously thinking about transfer of learning and working to increase it.

8. Regular in-class and homework assignments.

It may be that your students have been schooled in these approaches to learning. More likely, however, many of these ideas will be new to your students. Thus, quite a bit of your initial effort in teaching the problem-solving ideas will be to teach students to deal with these instructional methodologies.

Don't be overly bothered if you encounter resistance. We give young people a great deal of credit for their flexibility. However, in many ways they are resistant to change. The educational change literature provides solid evidence of how students resist changes in instructional methodology. You are apt to hear statements such as "This isn't the way Ms. Smith did it!"

Decide in advance how you will deal with such resistance to change. Work out one or more strategies. Student resistance to change provides you with an excellent opportunity to address the issue of change and how one copes with change. Are adults more resistant to change than children? This is an excellent topic for small-group and whole-class discussion and for journal writing. It is appropriate to spend class time addressing this issue.

Strategies

A strategy is a plan of attack on how to deal with a certain type of problem. You know a variety of strategies for dealing with unruly students and the bureaucracies of the school system. You learned these by receiving formal preservice training, by talking with other teachers, and by trial and error. The strategies you have are likely effective in most cases. However, there is no guarantee that they will be appropriate in every situation or that they will always be successful. (Note that trial and error is a widely used strategy in a wide range of problem situations. Often there are more powerul strategies that can be used.)

It is important that students become aware of the strategies they use in coping with problems. They should learn that it is possible to learn additional (perhaps better) strategies from formal schooling, from friends, from parents and other adults, from trial and error, and so on. The idea of strategies is one of the most important ideas in problem solving.

Coordination With Computer Literacy Courses

An underlying theme in every course should be "learning to learn." Computer literacy courses should also have an underlying theme of problem solving and roles of computers in problem solving. A computer literacy course provides an environment in which students can explore their own learning styles and work on learning to learn. Here are a few examples of types of questions you can explore with your class that will help relate the Chapter 1 materials to several general types of computer literacy courses.

1. Computer applications.

    A. What features are common to all word processors (or to some other generic piece of software, such as a database)? You can also ask this question about computer games. To what extent does learning one of these features on one particular piece of application software carry over to more easily learning a similar feature on a different piece of application software?

    B. When you are learning to use a word processor (or other generic software), what is your preferred style for learning? For example, do you like to experiment on your own, have the teacher explain it, read a book, or watch a fellow classmate learn it? Is your preferred learning style the same as for all other students in the class? Does it work equally well for all pieces of application software?

    C. In what sense is "Use a word processor" a good strategy for solving a writing problem? The same type of question can be asked for other types of application software and other problems. For example, in what sense is "Use a word processor" a good strategy for solving an information storage and retrieval problem? In what sense is "Use a word processor" a good strategy for solving an arithmetic computation problem?

2. Computer programming.

    A. What learning strategies do you use in learning a new "primitive" or feature in a programming language?

    B. How do you study for a programming test? Is it the same way that other students in the class study for programming tests? Is it the same way you study for a test in other courses?

3. Computer awareness, including exploration of social and vocational issues.

   A. What came before the Information Age? What do you think will come after the Information Age? How do such changes affect people? How do they affect you?

   B. How can you tell if a person is computer literate? Are you computer literate? Why would a person want to be computer literate?

   C. Is the definition of computer literacy changing? If you are computer literate at the end of this course, will you still be computer literate 20 years from now? (Here, we are assuming that you won't forget what you have learned in the course.)

Lesson Plan 2. Our Changing World

Primary Goals
1. Students will learn to make use of journaling as an aid to learning.

2. Students will be introduced to changes going on in our world and some of the roles of technology in these changes.

Prerequisites
1. (General) It is assumed that students have read the Preface and have considerable awareness of how technology is affecting their lives.

2. (Specific) None.

Materials Setup
1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson fits comfortably into one class period. Allow students 10-15 minutes to read Chapter 1: Introduction. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary.

Other very important terms and expressions receive less specific attention. Key vocabulary and expressions from Chapter 1 include:

advance organizer
basic skills
higher-order thinking skill
Information Age

lower-order thinking skill
memorize, look it up, figure it out
strategy

Notice that most of these are listed in Activity 2 at the end of Chapter 1 in *Problem-Solving Models for Computer Literacy*. In each chapter there is an activity that focuses on vocabulary.

Objectives

1. Students will participate in a whole-class brainstorming activity to list ways in which the world is changing.

2. Students will introspect on thinking and on learning to think.

3. Students will write in their journals.

Description

Background

Talking, writing, and thinking are closely intertwined. Thinking can be viewed as "talking silently to yourself." Writing can be viewed as a way of representing talking and as an aid to the careful organization of thinking/talking. Thus, introspection, participating in group brainstorming, participating in small-group discussions, and journaling are all important ways to practice thinking.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Then accept several students' responses. (Be aware that a long wait time allows students to practice higher-order thinking skills rather than just saying the first thing that pops into their conscious minds.)

2. Display Chapter 1 Overhead Transparency 1: Setting Up Your Journal. Help students get started in using their journals. Have them write on some important idea they remember from the Preface.

3. Discuss how journals will be used in your class. For example, if they are to be completely personal and private, make that very clear. Indicate that you expect that they will write in their journals each time the class makes use of *Problem-Solving Models for Computer Literacy* or focuses on ideas from the book.

4. Have your students spend a couple of minutes reading the first part of Chapter 1: Introduction. You may want to use Chapter 1 Overhead Transparency 2: Organize Your Thinking.

5. Engage your class in a brief discussion of some possible meanings of the saying "You can lead a horse to water, but you can't make it drink." Relate this to the role of the teacher and the role of students in school.

   Remember that each whole-class discussion in these lesson plans can begin as small-group cooperative discussion and brainstorming sessions. If you take this approach, you may want to provide each group with butcher paper and a felt marker. Each group is to produce results that are then posted in the front of the room and that serve to facilitate whole-class discussions. If you use this approach, each lesson plan will likely take an extra class period of time to complete.

6. Display Chapter 1 Overhead Transparency 3: Using Your Journal. Notice that the overhead illustrates both general comments and specific personal comments from a student. Stress that journal entries should frequently contain personal comments.

7. Display Chapter 1 Overhead Transparency 4: The World Is Changing. Engage your students in a group brainstorming process to make a long list of ways in which the world is changing and what is leading to the change.

   As time permits, this activity can be expanded into a discussion of how these changes affect the individuals in the class and other people in the world. The word "change" does not imply "change for the better." For each change that is suggested, you might focus the discussion on the good and the bad aspects of the change.

8. Discuss the organization of the activities at the end of the chapter. Relate the discussion to the saying "You can lead a horse to water, but you can't make it drink."

9. Have students read Chapter 1 and do Activity 1 at the end of the chapter.

10. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to read Chapter 1 and begin to make regular use of their journals. Students are to do Activity 1 at the end of Chapter 1.

Student Learning Indicators

1. Formative evaluation (for the teacher).

   - Students were actively engaged and had fun.
   - An atmosphere of discovery-based learning was created and maintained.
   - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
   - You were satisfied with how well the class went.
   - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

   - All students were engaged; at least half of them spoke at least once.
   - All students wrote in their journals.

Extensions and Follow-up

For homework, encourage students to think about ideas discussed in class.

Notes

Journaling is a powerful idea that is applicable in every academic field. You might want to talk about this with some of your fellow teachers. Perhaps you can convince some of them to make use of journaling in the classes they teach.

Lesson Plan 3. Strategies

Primary Goals

1. Students will be introduced to the the ideas of learning strategies for solving problems and learning to use tools as an aid to solving problems.

2. Students will learn about lower-order thinking skills and higher-order thinking skills.

Prerequisites

1. (General) It is assumed that students have read Chapter 1 and have begun to do some writing in their journals.

2. (Specific) None.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson fits comfortably into one class period. It can be extended to two periods by allowing more time for class discussions and assigning more of the activities at the end of the chapter.

Glossary

Key vocabulary and expressions from Chapter 1 include:

advance organizer
basic skills
higher-order thinking skill
Information Age
lower-order thinking skill
memorize, look it up, figure it out
strategy

Objectives

1. Students will participate in a whole-class discussion on memorization, "looking it up," and "figuring it out" as modes of learning.

2. Students will construct arguments for and against allowing the use of calculators at all times, even on tests.

3. Students will participate in a whole-class discussion of lower-order and higher-order thinking skills.

4. Students will make a personal list of strategies they frequently use in solving problems and will contribute to the creation of a whole-class list of strategies useful in solving problems.

5. Students will write in their journals.

Description

Background

There are many ways to get better at solving problems. One way is to learn special purpose and general purpose strategies that can be used either on specific sets of problems or on a wide range of problems. Later parts of this book focus on common strategies used in problem solving. The brief introduction given in Chapter 1 is designed merely to introduce the vocabulary and to serve as an advance organizer for the topic.

A second way to get better at solving problems is to learn to make use of tools designed to help one solve problems. The hand-held calculator is an example of such an aid to problem solving. While the National Council of Teachers of Mathematics has been strongly advocating the use of calculators in schools since about 1980, this is still a controversial issue in many schools. Perhaps you have a strong personal opinion on this subject.

Much of what students learn in school falls into the category of lower-order thinking skills on Bloom's taxonomy. However, much of what problem solving is all about involves higher-order thinking skills. Students can learn to distinguish between these two levels or types of thinking skills. They can begin to take increased responsibility for their own learning.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Some students will page back through their journals or look in their textbook. That is okay. Then accept several students' responses. This

approach to starting a class can be used throughout the course. Its purpose is to get students started thinking about what they have been learning and are learning. You are strongly encouraged to call on one or more students who do not volunteer to provide a response.

2. Display Chapter 1 Overhead Transparency 5: Memorize, Look It Up, Figure It Out. Discuss the idea that these are three different ways to "know" something. Point out that one person might think it is important to memorize something (like a phone number) while another person might feel it is better to just look it up.
3. Have students work individually to make up personal examples of things they memorize, learn to look up, and learn how to figure out. Then use the overhead to collect examples from a number of students. Do not be judgmental. Rather, look for diversity. Look for examples where, from different students' points of view, items fall into two or perhaps all three categories.
4. Display Chapter 1 Overhead Transparency 6: Strategies. Engage students in a discussion of the relative merits of memorizing, looking it up, and figuring it out as three different strategies for dealing with material covered in school and outside of school.
5. Display Chapter 1 Overhead Transparency 7: Is It "Cheating" to Use a Calculator? Engage the class in a brief discussion of the topic. Perhaps students, teachers, and parents have differing views on the topic.
6. Have each student figure out arguments on both sides of the questions about calculators. Then use the overhead to summarize good arguments on each side of the issue.
7. Display Chapter 1 Overhead Transparency 8: Lower-Order and Higher-Order Thinking Skills. Briefly review these ideas.
8. Have each student make up an example of a lower-order thinking skill question on ideas covered during the first part of the class. Provide quite a bit of wait time. Then use an overhead to display several of their examples.
9. Have each student think of an example of a higher-order thinking skill question on ideas covered during the first part of the class. Provide quite a bit of wait time. Then use an overhead to display several of their answers.
10. Give students an assignment. A suggested assignment is given under Student Activities in the next section of this lesson plan. Make sure that Activity 3 from the end of Chapter 1 is included in the assignment. Be aware that

research strongly supports the value of frequently assigning homework. In this course, assign homework that requires use of higher-order thinking skills.

11. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 1 Overhead Transparency 9: Chapter 1 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 3, 4, and 5 at the end of Chapter 1.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; at least half of them spoke at least once.
    - All students made written notes on possible answers to the discussion questions raised in class.
    - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage students to talk to their parents and other adults about what they think about the use of calculators. Have them bring up the topic in a math class and in a science class they are taking. Compare and contrast the responses of the math and science teachers.

Notes

The class discussion on the use of a calculator may lead students to question their math teachers. You might want to warn the math teachers that you will be discussing this topic in your class.

Additional Activities for Chapter 1

Note: These additional activities might be assigned as homework or be used for class discussion. Some may be appropriate for use as assessment activities. Some of the additional activities include a brief discussion of possible applications in a course.

1. What has changed during the past 50 years? Have cars changed a lot during the past 50 years? Has medicine changed a lot? Make a time line showing major changes. You may want to use computer software to help do this. You might want to get information for the time line by interviewing older people you know.

   This is a rich topic. The Information Age is a lot different from the Industrial Age that came before it. There has been a lot of change during the last 50 years. This change affects all of us. Students face an adult life of continued rapid change. You want them to think about such change and how they will deal with it.

   This activity can be done as an individual exercise, a small-group exercise, or a whole-class exercise. The time line can be created from scratch using a programming language such as BASIC or Logo, or you can use a commercially produced piece of time-liner software.

2. How do you learn things? Is there a difference between how you learn to get better at writing and how you learn to get better at math? Write two short letters to an imaginary friend. The first letter should explain how to get better at writing. The second letter should explain how to get better at math.

   This is a thinking-about-learning activity. The goal is to get students to become more consciously aware of their thinking and learning processes. This goal is strongly supported by research.

3. What is your typing speed? What is your handwriting speed? What is your hand-printing speed? Figure out a good way to find answers to these questions. You may want to do this in a small-group discussion. Then find answers for your own speeds.

Chapter 1 Overhead Transparency 1
Setting Up Your Journal

Today's Date **Page 1**

IMPORTANT IDEA FROM THE PREFACE

I think the most important idea in the Preface is that people can get smarter. I know that I am getting smarter. I can solve lots of problems that my younger brother can't solve. I couldn't solve them when I was his age.

Chapter 1 Overhead Transparency 2
Organize Your Thinking

ORGANIZE YOUR THINKING

You live in a complex and rapidly changing world. One purpose of schools is to help you learn to cope with the types of problems you will encounter when you become an adult. This means that you need to:

- Learn how to learn.
- Get better at solving problems.

There are many ways to get better at problem solving. One way is to write ideas in your journal that occur to you as you read.

Chapter 1 Overhead Transparency 3
Using Your Journal

Today's Date **Page 1**

LEADING A HORSE TO WATER

The horse might not be thirsty. You can put water in front of a horse, but it might not be interested in drinking right then.

In the same way, you can put good ideas in front of a student. However, the student might not want to learn the material. The student might not be thirsty for knowledge at that time.

Of course, you can try to force the student to learn. That may not work very well. I learn best when I want to learn. I learn best when I am interested in the material.

Chapter 1 Overhead Transparency 4
The World Is Changing

Some of the ways in which the world is changing.

1. People live longer—because of better medicine.

2.

3.

4.

5.

6.

7.

8.

9.

10.

44

Chapter 1 Overhead Transparency 5
Memorize, Look It Up, Figure It Out

Think about things you study in school. Think of two examples in each category.

1. **Something worth memorizing.**

2. **Something worth learning how to look up.**

3. **Something worth learning by figuring it out.**

Chapter 1 Overhead Transparency 6
Strategies

A strategy is a plan of attack. A strategy is a general way to try to solve problems. Here are a few examples.

1. **Break big problems into smaller problems. (The smaller problems may be much easier to solve.)**
2. **Draw a picture or a diagram to help you see what is happening in the problem. (The human mind is very good at dealing with pictures.)**
3. **Use brainstorming, either by yourself or in a group. (This is a good way to get some ideas about a hard problem.)**
4. **Make use of reference books. (A good way to solve a problem is to look up how to do it in a book.)**

Later parts of *Problem-Solving Models for Computer Literacy* devote a lot of time to strategies.

Chapter 1 Overhead Transparency 7
Is It "Cheating" to Use a Calculator?

Some people think that students should be allowed to use a calculator any time they want to, even on tests.

Think of two good arguments in favor of this.

1.

2.

Think of two good arguments against this.

1.

2.

Chapter 1 Overhead Transparency 8
Lower-Order and Higher-Order Thinking Skills

Lower-Order: Columbus discovered America in the year ____.

Higher-Order: Columbus discovered America in the year 1492. What was he trying to accomplish on his historic voyage, and why was it important to try to accomplish it?

Lower-Order: The Earth orbits about a star we call the ____.

Higher-Order: The Earth orbits about a star we call the sun. How do we know this? (You might want to describe several different scientific experiments that could be used to prove the assertion.)

Lower-Order: The name of the first president of the United States is ____.

Higher-Order: The name of the first president of the United States is George Washington. What was the process that led to his becoming president, and why didn't he become the king of the United States?

Chapter 1 Overhead Transparency 9
Chapter 1 Summary

CHAPTER 1 SUMMARY

Here are four good ways to get better at problem solving:

1. **Learn reading, writing, and arithmetic.**
2. **Learn a number of general purpose strategies for solving problems.**
3. **Learn to use tools, such as the computer, that help solve problems.**
4. **Practice solving problems.**

Chapter 2. You Are a Smart Person Overview

Rationale and Overview

Problem-Solving Models for Computer Literacy has two major goals:

1. To help students get better at solving problems.

2. To help students learn some of the roles of computers as an aid to solving problems.

There is an immense literature on problem solving, critical thinking, higher-order cognitive skills, decision making, and a variety of other closely related topics. In this book we lump all of these topics together under the general title of problem solving.

By the time students get to the classes you teach, they have repeatedly demonstrated that they are smart and that they are good problem solvers. They have successfully coped with life in our society and with our school system—they have survived! However, there are many different types of problems and many different types of "smarts." Some students are street-wise, while others are school-wise. Some have tremendous "people" skills while others seem to prosper as "loners."

One of the things we know about problem solving is that success breeds success. Our school system and our society tend to reward people who are good at solving school and nonschool problems. This positive feedback promotes putting in the time, energy, and thought needed to become still better at problem solving.

There has been a lot of research about how people differ in their learning styles. A good summary of some of the key ideas is given by Robert Sternberg (1990). One of the main points he makes is that if a teacher is not aware that students have widely varying learning styles, the teacher is apt to (subconsciously) reward students whose learning styles are like those of the teacher. That is, many students will be made to feel inadequate because their learning styles do not match those of the teacher. This contributes to poor self-esteem, poor progress in learning to learn, and poor problem-solving ability.

You, as a teacher, want to create a learning environment that strongly encourages your students to become better problem solvers. One starting point is to help all of your students to realize that they are already good at solving problems. All of your students are "smart."

Part of being "smart" is making effective use of one's brain. All students can think. All students can get better at thinking. Metacognition is a field of study that focuses on thinking about thinking. Research indicates that even at the primary school level, students can think about their own thinking processes. This metacognition helps to make them better thinkers.

Chapter 2 focuses on the idea that all students are smart and can get smarter. All students can think and can get better at thinking. All students can gain increased knowledge and awareness of their current strengths and weaknesses as problem solvers. This knowledge can serve as a basis for getting better at solving problems.

The chapter also explores the idea of a machine or a book being smart. The goal here is to get students to think about how their smartness differs from that of machines and books.

Coordination With Computer Literacy Courses

An underlying theme in every course should be "getting better at thinking about and solving the types of problems addressed in the course." Computer literacy courses focus on computer-related tools both as an aid to solving problems and as a source of problems. Thus, they lend themselves to the explicit study of one's own thinking process in learning to solve problems and in attempting to solve problems.

Here are a few examples of types of questions you can explore with your class that will help relate the Chapter 2 materials to several general types of computer literacy courses.

1. Computer applications.

   A. Select a specific computer application, such as a database. What problems is it designed to help solve? Give examples of important problems both in school and outside of school where the computer application is useful. Then give examples of somewhat similar problems where the computer is not particularly useful. For example, a city bus schedule might well be stored in a computer database. But a printed copy of the schedule for the bus routes you use is much more valuable to you.

   B. Select a specific computer application, such as a database. What role does the human mind play in making effective use of this computer application?

   C. In what ways does being good at using a computer application make you smarter?

2. Computer programming.

    A. Name some problems a computer cannot solve. Name some problems a computer can solve. Compare and contrast the thinking skills of people with the capabilities of computers in solving difficult problems.

    B. Can a computer think? We often anthropomorphize computers—endow them with human characteristics. What are advantages and disadvantages of doing this? Does it get in the way of learning to program and being responsible for the performance of one's programs?

3. Computer awareness, including exploration of social and vocational issues.

    A. Is it possible that eventually we will have computers that are "smarter" than people? What would that do to our society?

    B. What are appropriate roles for people in creating and solving problems versus appropriate roles for computers?

Lesson Plan 4. We Are All Smart

Primary Goals

1. Students will learn a definition of a "smart person" and that they are smart.
2. Students will learn some ways in which they can get smarter.

Prerequisites

1. (General) It is assumed that students have read Chapter 1 and have an intuitive understanding of ideas such as learning to learn, problem solving, and higher-order thinking skills.
2. (Specific) Students can read, follow directions, and write well enough to complete the quiz at the beginning of Chapter 2 without help. (If this is not the case, provide them with appropriate help. You want every student to be successful on this quiz.)

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.
2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson fits comfortably into one class period. Allow students 10-15 minutes to read Chapter 2: You Are a Smart Person. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary.

Other very important terms and expressions receive less specific attention. Key vocabulary and expressions from Chapter 2 include:

easy (to solve) problem
hard (to solve) problem
metacognition
smart person
think

Objectives

1. Students will do the journal-writing activity Fun Things That I May Do After School Today.

2. Students will write about such ideas as "Is a book smart?" and "Is a machine smart?"

3. Students will have increased ability to talk about their own strengths and weaknesses as a smart person. They will display the ability to do metacognition.

Description

Background

All students are smart and all can get smarter. Here we are defining "smart" as the ability to understand and solve the types of problems one encounters both in school and outside of school. It also includes being able to "do" things like build a model, repair a car, cook a meal, create and tell a story, and compose music. All students have both strengths and weaknesses in their smartness. Increased self-awareness of these strengths and weaknesses can contribute to a student getting smarter. There are many tools, such as reading, writing, arithmetic, and computers, that assist one's smartness. Learning to use these tools increases one's smartness.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Then accept several students' responses.

2. Display Chapter 2 Overhead Transparency 1: Organize Your Thinking. Use this as an advance organizer for the lesson.

3. Display Chapter 2 Overhead Transparency 2: What Does It Mean to Be Smart? Facilitate a whole-class brainstorming session on this topic. Continue until students have provided you with a reasonably long list of ideas. Do not be judgmental.

Remember, each whole-class discussion of this sort can instead begin with a small-group cooperative brainstorming and discussion activity.

4. Have your students spend a few of minutes reading the first part of Chapter 2: You Are a Smart Person. Make sure all students do the journal-writing exercise Fun Things That I May Do After School Today.

5. Engage your class in a brief discussion of whether animals such as cats, dogs, dolphins, or whales can plan alternative activities that they might carry out later in the day. How would one design an experiment to test this aspect of smartness?

6. Display Chapter 2 Overhead Transparency 3: Ways of Getting Smarter. Engage your class in a brainstorming session on ways to get smarter.

7. Have students read the remainder of Chapter 2 and do activities 1, 2, 5, and 6 at the end of the chapter.

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to read Chapter 2 and continue making regular use of their journals. Students are to do activities 5 and 6 at the end of Chapter 2.

Student Learning Indicators

1. Formative evaluation (for the teacher).
   - Students were actively engaged and had fun.
   - An atmosphere of discovery-based learning was created and maintained.
   - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
   - You were satisfied with how well the class went.
   - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
   - All students were engaged; at least half of them contributed in the whole-class brainstorming activities.

- All students successfully completed the quiz at the beginning of Chapter 2.

- All students wrote in their journals.

Extensions and Follow-up

Encourage students to think about how one might test how smart an ant or a fly is. Perhaps they might want to ask their science teacher this question.

Notes

Smartness, as defined in this chapter, is only partially related to intelligence. Intelligence and ways to measure intelligence are very complex topics. There is now considerable agreement that intelligence can be increased. In recent years Howard Gardner (1983) and Robert Sternberg (1988) have written readable books on intelligence that capture many of the key and controversial ideas.

Lesson Plan 5. Metacognition on Solving Easy and Hard Problems

Primary Goals

1. Students will increase their skill at metacognition.

2. Students will learn to recognize some of the characteristics that make a problem relatively easy or relatively difficult for them.

Prerequisites

1. (General) It is assumed that students have read Chapter 2 and are comfortable in doing journal-writing activities.

2. (Specific) Students understand that a useful definition of "smartness" is the ability to understand and solve the types of problems one encounters.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson fits comfortably into one class period. It can be extended to two periods by allowing more time for class discussions and assigning more of the activities at the end of the chapter.

Glossary

Key vocabulary and expressions from Chapter 2 include:

easy (to solve) problem
hard (to solve) problem
metacognition
smart person
think

Objectives

1. Students will participate in a whole-class discussion on different kinds of problems they encounter in school and outside of school.

2. Students will list important problems they find easy to solve.

3. Students will list types of problems they find difficult to solve.

4. Students will practice metacognition on what makes problems particularly easy or hard for them.

Description

Background

Research on problem solving indicates that the difficulty of a problem is highly dependent on the problem solver. A problem might be very easy for one person and very difficult for another, even though both have relatively similar intellectual abilities and education.

Through careful metacognition, a student can come to recognize his or her strengths and weaknesses as a problem solver. This provides useful information in getting better at solving problems.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Some students will page back through their journals or look in their textbook. That is okay. Then accept several students' responses. This approach to starting a class can be used throughout the course. Its purpose is to get students started thinking about what they have been learning and are learning.

2. (For comic relief) Display Chapter 2 Overhead Transparency 4: How to Measure the Smartness of a Flea. Have each person in the class write down two or more ways to tell if one flea is smarter than another. Suggest that it is okay for the ideas to be humorous. Allow about two minutes of writing time. Then call on students at random, soliciting one idea from each student you call on.

3. Debrief the students after the flea activity. Point out that it may be difficult to solve the problem of whether one flea is smarter than another flea. A researcher might spend years on such a problem.

4. Display Chapter 2 Overhead Transparency 5: What Makes a Problem Easy? Do a whole-class brainstorming session on what makes a problem easy. Be aware that some students may think that a particular type of problem is easy while others think it is hard. You might ask for a show of hands on each type of problem named. Students can vote for "easy" or "not so easy."

5. Have students do the journal-writing activities Important Problems That Are Easy for Me and Practice in Metacognition from the text.

6. If time permits, do a whole-class debriefing on these journal-writing activities. The goals are to add to the list compiled above on What Makes a Problem Easy and to help class members discover that a problem may be easy for one person and difficult for another, or vice versa.

7. Assign activities 3, 4, 7, and 8 from the end of the chapter as work to be done in class or outside of class. Tell students that this is a required assignment to be turned in at the beginning of the next class meeting.

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 2 Overhead Transparency 6: Chapter 2 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 3, 4, 7, and 8 at the end of Chapter 2. Students are to turn these in at the beginning of the next class meeting.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; at least half of them spoke at least once.

- All students made written notes on possible answers to the discussion questions raised in class.

- All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage your students to ask other people for examples of hard problems. For example, they might ask other students, teachers, siblings, or their parents for examples of problems that they find hard to solve.

Notes

One of the things that makes a problem hard to solve is that it is unfamiliar. Research on problem solving indicates that one needs a great deal of domain-specific knowledge—that is, knowledge of the particular subject areas the problem concerns—to be good at solving a particular type of problem. If you are going to be good at solving math problems, you will need to learn a great deal of mathematics.

Researchers and writers in the field of problem solving argue among themselves about how much problem solving depends on domain-specific knowledge and skill, and how much one can transfer knowledge and skill across different problem domains.

Additional Activities for Chapter 2

1. Researchers in artificial intelligence have been working for many years to develop computer programs that are very good at playing chess. At first these programs were not very good. But gradually they have gotten better and better. Now, the best computer chess program is ranked among the top 500 chess players in the whole world.

   What are your feelings about this type of computer program? Do you think it is fair for this program to compete in chess tournaments with humans? Suppose that a better program is written so that the computer never loses. Would people still want to learn to play chess?

   This same type of question can be raised about other machines. A fast sports car can accelerate from 0 to 60 miles per hour in just a few seconds. No human will ever be able to run 60 miles per hour. But we still have track meets.

2. This activity requires having enough calculators for about half of the class. It is a teacher-facilitated activity. Divide the class into two groups. One group gets to use calculators and the other does not. Now give the class a test consisting of a variety of multiplication and division problems that can be done on a calculator. Make sure that many of the numbers have quite a few

digits in them so that it will take a long time to do one of the calculations by hand. Tell the students it is a timed test, so they are to work quickly but accurately.

Watch them as they work. As soon as a one or two of the students in the calculator group seem to have finished the whole test, call "time." Read off the answers, and let each person grade his or her own paper. Gather some statistics about the average number of correct answers from each group. Use this to start a class discussion on whether it is fair to use calculators. You might ask whether it is fair for the math teacher to *not* allow calculators on tests and in doing homework.

This activity gets at a critical issue. Many students believe that it is cheating to use a calculator. (But most adults own and use calculators!) Is it cheating to use an elevator instead of walking up and down the stairs? Is it cheating to use a car or a bicycle instead of walking? Why is it cheating to make use of a calculator?

Many students who feel it is cheating to use a calculator do not think it is cheating to use a computer. What are the similarities and differences? Very small, easily portable computers are now being made. Some look just like a calculator. Is there really a difference between a calculator and a computer? Suppose all people owned their own personal computers that they could carry with them all of the time. Then would it be cheating to use a calculator or a computer?

3. Pick a piece of software designed to solve some category of problem. For example, pick software designed to draw a graph of data. Demonstrate it to the class. If time permits, have a contest between the computer and several students you know who are very good at solving the problem by hand.

   Use this for a class discussion just as in additional Activity 2 above. You are raising the following question: If a computer can solve or help solve a problem, what should students learn about solving that kind of problem?

4. In 1966 Joseph Weizenbaum, a professor at the Massachusetts Institute of Technology, published a paper describing ELIZA, a computer program that could carry on a conversation with a person. This program has been rewritten many times, and many different versions now exist. Most likely you can find a public domain version of the program that will run on the type of computers available to your students. Students of all ages enjoy carrying on a conversation with a computer. Let your students play with this program. Use this experience as a lead-in to discussing whether a machine can be smart.

5. In 1950 Alan Turing published a test for measuring whether a machine is intelligent. It is an imitation game. A computer program is written that

attempts to make the computer respond as if it were human. People in one room communicate via computer terminals to the computer and a person located in another room. The people ask questions of the human and the machine, attempting to tell which is which from the answers.

A variation of this game is to place a boy and a girl in a room and to communicate with them via computer terminal or typed messages. One of the two students attempts to "imitate" being of the opposite sex in terms of how he or she answers questions submitted by people in the other room. The goal of the people asking questions is to attempt to tell which is the boy and which is the girl from the answers.

The question of what constitutes intelligence is interesting and difficult. It can lead to lively class discussions. Some of the discussion may focus on robots in movies or television.

Chapter 2 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

The ability to think before you act is very important in solving problems. Most people are good at considering alternatives. This chapter is about:

- **What it means to be "smart."**
- **Thinking about your own thinking.**
- **Thinking about what kinds of problems are easy for you.**

Chapter 2 Overhead Transparency 2
What Does It Mean to Be Smart?

A person is smart if he or she:

1. **Is good at dealing with people.**

2.

3.

4.

5.

6.

7.

8.

9.

Chapter 2 Overhead Transparency 3
Ways of Getting Smarter

1. Spend time talking to smart people.

2.

3.

4.

5.

6.

7.

8.

9.

Chapter 2 Overhead Transparency 4
How to Measure the Smartness of a Flea

1. **Place it midway between a cat wearing a flea collar and one not wearing a flea collar. See which way it goes.**

2.

3.

4.

5.

6.

7.

8.

9.

Chapter 2 Overhead Transparency 5
What Makes a Problem Easy?

A problem is easy if:

1. **You have solved it many times before.**

2.

3.

4.

5.

6.

7.

8.

9.

10.

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Chapter 2 Overhead Transparency 6
Chapter 2 Summary

CHAPTER 2 SUMMARY

Metacognition—thinking about thinking—is very important. You can think about your own thinking. This is one way to get better at solving problems. Some other key ideas in this chapter include:

1. You know that you are good at solving some types of problems.

2. You can think about why some problems are easier for you than other problems.

Chapter 3. What Is a Problem?
Overview

Rationale and Overview

There is a considerable amount of research literature on problem solving. A brief summary of the findings includes:

1. One needs to know a lot about the specific subject matter of a problem domain in order to be good at solving the problems in that domain. Being good at solving chess problems does not automatically make one good at solving interpersonal problems or problems in other domains.

2. There is some transfer of problem-solving knowledge and skills from one domain to another. This can be increased by appropriate instruction and practice.

3. Transfer of problem-solving skills between domains is enhanced by metacognition and by having a good working vocabulary to talk about problem solving.

Much of the design of *Problem-Solving Models for Computer Literacy* focuses on the above ideas. Chapter 3 addresses the issue of "What is a problem?" It gives a formal, four-part definition of the word "problem." It talks about problem-like situations that have some of the characteristics of a formal problem but lack one or more of the four parts in the formal definition.

A good working knowledge of a formal definition of "problem" is useful in addressing problems from many different domains. This is because one of the most important steps in problem solving is to "Understand the problem." What does it mean to understand a problem? Part of what it means is to work to have a clearly defined problem—that is, one in which all four parts of the definition are clearly identified. Thus, a student can get better at solving problems by memorizing the four-part definition and by developing skill in using this definition in a wide variety of settings. (A good memory is a good aid to problem solving and to getting better at solving problems. However, it takes more than good memorization skills to be good at solving problems.)

A key component in the four-part definition is ownership. Ownership leads to involvement, to an investment of time and energy, to persistence.

The idea of ownership raises important educational questions. Many students have little or no interest in the types of problem situations posed by teachers and/or school textbooks. The problem situations seem totally unrelated to their current lives and interests. Thus, the students do not accept any ownership of these problem situations. The problem situations do not become problems for the students. Sometimes the students make a half-hearted effort to address the problem situation, and other times they ignore it completely. Threats of poor grades do little to alleviate the situation.

The key point is, *without ownership, there is no problem.* Good teachers are good at helping to provide students with problem situations that are both relevant to the curriculum and relevant to the students. These are problem situations where students are likely to build ownership. One approach is to help students to learn to pose their own problems. Problem posing is developing as an important part of the overall field of problem solving. Initially you will likely find that your students have difficulty in posing problems that require higher-order thinking skills. Give them lots of encouragement as they begin to make progress in this endeavor.

Coordination With Computer Literacy Courses

The computer is a tool designed to help solve problems. Every computer literacy course should have problem solving as a central focus. The emphasis may be on exploring the types of problems computers help create, such as in a computers and society course. (Note that we did not have computer crime before we had computers.) Computers have contributed significantly to the problem of "Big brother is watching you." Or the focus may be on actually learning to make use of the computer as an aid to solving specific types of problems.

In either case, problem posing is important. Name some of the problems that computers are creating. Name some problems that can be solved using a particular software application package. Name some problems that can be solved using a particular level of programming skill in a particular programming language.

Here are a few examples of types of questions you can explore with your class that will help relate the material in Chapter 3 to several general types of computer literacy courses.

1. Computer applications.

    A. Select a specific computer application, such as a database. What problems is it designed to help solve? Give examples of problems both in school and outside of school where the computer application is useful to you personally. Make sure that these are clearly defined problems, with all four components of each problem being clearly specified. (This relates to clearly defined problems, ownership, and problem posing.)

    B. Suppose you are familiar with several different pieces of generic application software, such as a word processor, database, and graphics package. Pose a problem that is more effectively addressed by use of a

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combination of two or more of these pieces of software than by any one individually.

C. Of the generic application packages you have studied, which is the most fun to use? Why? (This relates to ownership.)

2. Computer programming.

A. What is "fun" about learning to write computer programs? Compare and contrast programming with the level of "funness" of learning in other courses or developing other skills.

B. What makes a computer programming problem particularly hard? What makes a computer programming problem relatively easy? When is it appropriate for students to pose their own "homework" programming problems?

3. Computer awareness, including exploration of social and vocational issues.

A. Does the four-part definition of "problem" given in this chapter apply equally well to all disciplines? Or does it mainly favor technology-oriented problems that can be addressed by use of a computer?

B. What can students and teachers do to help increase student ownership of the types of problems deemed appropriate for students to study?

Lesson Plan 6. Formal Definition of the Word "Problem"

Primary Goals

1. Students will learn a formal, four-part definition of "problem."

2. Students will learn to identify the missing components in a problem situation that keep it from being a clearly defined problem.

Prerequisites

1. (General) It is assumed that students have read Chapter 2 and have an intuitive understanding of ideas such as learning to learn, problem solving, and higher-order thinking skills. Students can give examples of personally relevant problems that occur both in school and outside of school.

2. (Specific) Students understand that smartness is being able to solve the types of problems they encounter in school and outside of school.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson fits comfortably into one class period. Allow students 15-20 minutes to read Chapter 3: What Is a Problem? The Teacher Lesson Plans include two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 3 contains a much longer list of terms than the previous chapters. Be aware that most students cannot easily assimilate such a long list of new terms in a

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single class period. You will want to emphasize the use of this vocabulary throughout the remainder of the course.

clearly defined problem
computer program
cooperative learning
given initial situation
goal
ownership
poorly defined problem
problem
problem posing
problem situation
resources and restrictions

Objectives

1. Students will participate in a whole-class discussion focusing on "Alternatives" in some problem situations. The teacher displays these alternatives on an overhead projector.

2. Students will do the journal-writing activity My Definition of Problem.

3. Students will pose clearly defined problems from a given problem situation.

Description

Background

A clearly defined problem has clearly defined givens, goal, resources and restrictions, and ownership. A problem-like situation that has some but not all of these clearly defined components is called a problem situation. The process of moving from a problem situation to a clearly defined problem is one aspect of problem posing. It is important that students memorize and internalize the four-part definition of a clearly defined problem. It is important that students develop skill in recognizing when they are faced by a problem situation and that they gain increased skill in posing clearly defined problems from a problem situation.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Then accept several students' responses.

2. Display Chapter 3 Overhead Transparency 1: Organize Your Thinking. Use this as an advance organizer for the lesson.

3. Display Chapter 3 Overhead Transparency 2: Alternatives. Facilitate a whole-class brainstorming session on this topic. Continue until students have provided you with a reasonably long list of ideas. Do not be judgmental. The goal is to help your students realize that there may be many different goals or possible courses of action that arise from a problem situation.

   Remember that you may want to use small groups and cooperative learning techniques to approach this discussion topic.

4. Display Chapter 3 Overhead Transparency 3: Alternatives. Facilitate a whole-class brainstorming session on this topic. Continue until students have provided you with a reasonably long list of ideas. Do not be judgmental. The goal is to help your students realize that there may be many different goals or possible courses of action that arise from a problem situation.

5. Have your students spend a few minutes reading the first part of Chapter 3: What Is a Problem? Make sure all students do the journal-writing exercise My Definition of Problem. Give students enough time so that most of them read through the example called Halloween Costume Day at School.

6. Display Chapter 3 Overhead Transparency 4: Four-Part Definition of a Problem. Discuss the four parts, illustrating from the Halloween Costume Day example. Point out that there is a difference between having a clearly defined problem and solving the problem. Getting a clearly defined problem is often a first step in working to solve a problem. However, there are many clearly defined problems that have no solution.

7. Display Chapter 3 Overhead Transpanency 5: Brainstorming. Have your class brainstorm on what brainstorming is. (Note that they are metabrainstorming.)

8. As time permits, have your students continue reading Chapter 3. Assign Activity 1 at the end of the chapter.

9. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to read Chapter 3 and to continue making regular use of their journals. Students are to do Activity 1 at the end of Chapter 3.

Student Learning Indicators

1. Formative evaluation (for the teacher).

- Students were actively engaged and had fun.

- An atmosphere of discovery-based learning was created and maintained.

- You made frequent use of the Glossary words and provided positive reinforcement to students using these words.

- You were satisfied with how well the class went.

- Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

   - All students were engaged; at least half of them contributed in the whole-class brainstorming activities.

   - All students wrote in their journals.

Extensions and Follow-up

Have students pay attention to how people use the word "problem." Look for examples where people actually mean "problem situation" rather than "clearly defined problem."

Notes

Problem solving is an important component of every course your students are taking. Some teachers are explicit about teaching problem solving, while others do not even mention the word "problem." You want your students to become aware of these differences and to ask their teachers, "Why?" You want them to ask, "What are the main problems you are teaching us how to solve? Are these clearly defined problems?"

These types of questions are often challenging. You may want to spend some time discussing them with your fellow teachers. Warn them that some of your students will be raising these types of questions in their classes.

Lesson Plan 7. Posing Clearly Defined Problems

Primary Goals

1. Students will increase their skill at brainstorming in small groups.

2. Students will increase their skill in developing clearly defined problems from problem situations.

Prerequisites

1. (General) It is assumed that students have read Chapter 3 and are used to participating in whole-class brainstorming sessions.

2. (Specific) Students have memorized the four-part definition of "problem."

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson fits comfortably into one class period. It can be extended to two periods by allowing more time for class discussions and assigning more of the activities at the end of the chapter.

Glossary

Key vocabulary and expressions from Chapter 3 include:

clearly defined problem
computer program
cooperative learning
given initial situation
goal
ownership
poorly defined problem

problem
problem posing
problem situation
resources and restrictions

Objectives

1. Students will participate in a small-group brainstorming session.

2. Students will use the vocabulary Givens, Goal, Resources and Restrictions, and Ownership in their speaking and writing.

3. Students will pose a variety of possible relevant goals when they encounter a problem situation that lacks a clearly defined goal.

Description

Background

Problem solving is a human endeavor. Humans create and solve problems. One of the main goals of school is to help students gain increased skill at creating and solving a wide range of problems.

Quite often a problem situation will lack both a clear goal and clearly defined resources and restrictions. Brainstorming individually, in small groups, and in large groups is a powerful strategy for addressing this situation. All students can get better at this type of brainstorming by study and practice.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Some students will page back through their journals or look in their textbook. That is okay. Then accept several students' responses. This approach to starting a class can be used throughout the course. Its purpose is to get students started thinking about what they have been learning and are learning.

2. Display Chapter 3 Overhead Transparency 5: Brainstorming. Do a whole-class brainstorming session on "What is brainstorming?" and "Good ways to do brainstorming." The goal is to come up with a number of approaches to brainstorming. Point out that brainstorming is a *strategy*—a way to approach certain types of problems. It is not guaranteed to work and it is not relevant in every possible problem situation. But it is fairly useful in many different problem situations.

3. Divide the class into groups of three or four for an individual and small-group brainstorming activity. The topic is from the text:

   Pat's social studies teacher is talking about drunk driving. The teacher says, "Last year in this country about 25,000 people died because of drunk drivers." Pat thinks about her older brother's friend who drinks and drives. She feels scared.

   First, each person in the group is to do individual brainstorming on possible goals that Pat might set. Then share ideas in a small-group brainstorming session. The whole exercise should be completed in about 10 minutes.

4. Debrief the whole class on this exercise. What worked and what didn't work? What "ground rules" are needed within the groups to make the brainstorming proceed more smoothly and/or be more effective?

5. Using the same small groups, each group is to decide on a specific goal that Pat should work on. Then the small group is do a group brainstorming session on resources and restrictions that Pat faces in attempting to achieve this goal.

6. Display Chapter 3 Overhead Transparency 6: Possible Goals for Pat. Make a list of the goals that the different small groups selected. Briefly discuss similarities and differences. Emphasize the differences—the same problem situation may lead to many different goals being set. Ask your class for real-world examples of this. Have one or two in mind, in case they need some prompting. For example, perhaps the school lunchroom is noisy during lunch time. One group of people might set a goal of having all students sit quietly while they eat. Another group might set a goal of curbing the loudness of the small number of students making the most noise. Still another group might set a goal of allowing students to eat lunch off campus if they want—thereby decreasing the number of people making noise in the lunchroom.

7. If time permits, have the same small groups work together on Brainstorming About Too Much Homework, which is an activity at the end of Chapter 3 in the text.

8. Assign students activities 3, 4, 7, and 8 from the end of Chapter 3.

9. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 3 Overhead Transparency 7: Chapter 3 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level. This type of closing activity can be used at the end of any class period.

Student Activities

Students are to do activities 3, 4, 7, and 8 at the end of Chapter 3. Students are to turn these in at the beginning of the next class meeting.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; at least half of them spoke at least once.
    - All students made written notes on possible answers to the discussion questions raised in class.
    - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage your students to find examples of problem situations where different groups of people have decided on different goals. Tell them that you will be asking for examples at the beginning of the next lesson on problem solving. A good source of examples can be found in the area of environmental issues.

Notes

The development of clearly defined problems from problem situations is one of the most important ideas in problem solving. Different people will develop different problems from the same situation. A key aspect of a democratic society is that this can occur, and that the different groups are free to pursue their own particular aims. Free and open debate on the differing points of view (different goals, different applicable resources and rules) is critical. The ideas from Chapter 3 are suitable for use in a social studies course.

Additional Activities for Chapter 3

1. Problem posing is very important. Many leaders are good at problem posing. They can think of problems that are important to solve. They can think of

problems that many people want to have solved. They can organize people to work together in solving these problems.

This is a journal exercise. Do it for the next three days. Each day, in each class you are taking, pose a problem. Write it in your journal. The problem should relate to the class material you are studying. It should be important to you. It should be important to other people.

There is growing awareness of the importance of problem posing. Many colleges give courses on problem solving. It is only in recent years that some colleges have also begun to give courses on problem posing.

2. Here is a good way for you and a friend to work together to study for a test. Take turns making up problems for each other. Make up a problem you know you can solve. See if your friend can solve it. You may need to help your friend solve the problem. That will help you. You can learn a lot by explaining things to someone else.

This type of activity can be used in any course. One way to use it is in small groups. Each person in the group makes up a problem that he or she thinks is important and that is related to the material being studied. Then the whole group gets a chance to discuss and try to solve each of the problems.

This type of exercise is challenging and valuable. Initially, the students will all make up rather simple "fact-oriented" questions. They have been exposed to this type of question throughout their schooling. They may not have any idea of what constitutes a problem in social studies, in language arts, or in art.

A variation on this activity is to give students a test to look at. What parts of the test are lower-order skill, "memorized fact" types of questions? What parts of the test require more careful thinking or problem solving? Research indicates that students rather quickly adapt to the type of tests a teacher gives. If you want your students to get better at problem solving, give them tests that focus on higher-order thinking skills and problem solving. Research also indicates that most teacher-made tests focus almost exclusively on lower-order skills.

Chapter 3 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

This chapter contains a four-part definition of the word "problem." This definition is used throughout the rest of the book. A starting point in solving a problem is to gain a clear statement of the problem. This chapter will give you practice in:

- Metacognition, to understand the meaning of "problem."
- How to deal with problem situations that are not clearly defined problems.
- Brainstorming, a useful strategy in dealing with problem situations.

Chapter 3 Overhead Transparency 2
Alternatives

Pat wakes up in the morning and remembers that it is a school day. Pat thinks, "Most of my clothes are dirty. What shall I do?"

1. **Resolve to plan ahead next time.**
2.
3.
4.
5.
6.
7.
8.
9.

Chapter 3 Overhead Transparency 3
Alternatives

At breakfast, the television set is on. Pat hears the announcer talking about an African country: "The situation is grave. It is reported that 5,000 children are starving." Pat finds that it is hard to eat while thinking about these starving children.

1. **Find out more about the African country.**
2.
3.
4.
5.
6.
7.
8.
9.

Chapter 3 Overhead Transparency 4
Four-Part Definition of a Problem

1. Givens. There is a given beginning situation. This is a description of how things are, what is happening, what is known, and so on.

2. Goal. There is a desired final situation. This is a description of how you want things to be. What do you want to accomplish?

3. Resources and Restrictions. What types of things can you do that might help you achieve the goal? What resources do you have? Resources include skills, knowledge, time, energy, materials, machines, money, and so on.

   What are the restrictions and rules you must follow in working to solve the problem? Often these are not written down, but you know them. For example, YOU SHOULD NOT BREAK THE LAW. In taking a test, DO YOUR OWN WORK.

4. Ownership—importance to you. For something to be a problem for you, you must have some interest in solving it. You must accept some ownership.

Chapter 3 Overhead Transparency 5
Brainstorming

What is brainstorming? What are good ways to do it?

1. **People take turns providing ideas.**

2.

3.

4.

5.

6.

7.

8.

9.

Chapter 3 Overhead Transparency 6
Possible Goals for Pat

1. Share her feelings with her older brother.

2.

3.

4.

5.

6.

7.

8.

9.

10.

Chapter 3 Overhead Transparency 7
Chapter 3 Summary

CHAPTER 3 SUMMARY

A problem has four parts: Givens, Goal, Resources and Restrictions, and Ownership. A problem is said to be clearly defined if the givens, goal, and resources and restrictions are all clear.

Most problem situations are not clearly defined problems. This is especially true of real-world problem situations. It can take a lot of thinking to get a clearly defined problem from a problem situation. Brainstorming is often a useful strategy in this thinking process.

If a problem is clearly defined, it can be communicated to others. This allows groups of people to work together to solve the problem.

Chapter 4. A Four-Step Plan for Solving a Problem

Overview

Rationale and Overview

Chapter 3 provided a careful definition of the word "problem." It seems as though many people believe that any problem that can be named can be solved. How many times have you heard questions such as the following: "If we can land a man on the moon and successfully return him to earth, why can't we properly educate our children, clean up our cities, and end poverty?" A question like this strongly suggests that if we can name the problem (for example, "properly educate our children") we should be able to solve it.

Based on the definitions in Chapter 3, you recognize that "properly educate our children" is a problem situation rather than a clearly defined problem. It is a goal, but it is not a clearly defined goal. One way to answer the person who raises this question is to ask, "What do you mean by 'properly educate our children?'" This will likely lead to a heated debate, and eventually the problem situation may be resolved into a clearly defined problem.

Even then, however, there is no guarantee that the clearly defined problem can be solved. There are lots of clearly defined problems that have no solution. This means that no matter how long and hard a person works on these problems, they will never be solved.

The concept of an unsolvable problem is very important. The real world is full of unsolvable problems. However, school tends to only present students with solvable problems. Indeed, the problems students encounter in their courses can often be solved just by using the ideas they are currently studying in the course that presents the problem. Typically such problems do not require much in the way of synthesis of ideas and methods from previous or other courses.

This suggests two important tasks you should be working on throughout this course.

1. Help all your students to understand that there are many unsolvable problems.

2. Help your students gain some coping strategies to use when they encounter problems that are unsolvable or that are sufficiently difficult from their perspective that they appear to be unsolvable.

You can accomplish the first task by providing lots of examples and by helping your students learn to create their own examples. Eventually some of your students will take delight in posing unsolvable problems to their teachers and other people.

The second task is harder, partly because it is usually difficult to determine that a problem is unsolvable. A problem may be merely very difficult to solve or it may be well beyond one's current problem-solving abilities. There are lots of ways to cope with unsolvable problems. One very good way is to create a new problem that is closely related to the original one but that is solvable. This approach is also useful with problems that are very difficult or that are beyond one's current problem-solving abilities.

This chapter focuses on two general approaches to getting better at solving problems:

1. Learn some general ways to attack problems. This chapter gives a four-step plan that is useful in attacking a wide range of problems. (Chapter 5 gives some other general purpose methods for attacking problems.)

2. Learn to build on the work of other people. Each subject you study in school consists of some of the work of other people. Each subject has already been studied for many years by experts in that field. The experts have picked out some of the most important ideas. When you learn these ideas, you are building on the work of these experts.

The first lesson plan for this chapter focuses on the idea of an unsolvable problem and a general purpose, four-step plan that can be used to attempt to get started in solving almost any problem. The second lesson plan focuses on learning to build on your own previous work and on that of others. Computers can be very useful in this approach to problem solving.

Coordination With Computer Literacy Courses

A computer literate student should have a good understanding of the capabilities and limitations of computers. The student should know when a computer is apt to be a useful aid in solving a problem and when it is apt not to be useful. The student should know that a computer is not a magic "brain" that can solve all problems.

Here are a few examples of types of questions you can explore with your class that will help relate the Chapter 4 materials to several general types of computer literacy courses.

1. Computer applications.

   A. Select a specific computer application, such as a database. What problems is the database designed to help solve? Make up a sequence of questions that cannot be answered using the database. (Think of these as problems that cannot be solved when the restrictions are that you can only make use of the data in the database.)

   B. Take a look at some graphics software that includes a library of clip art as well as some powerful aids to drawing. In what sense does such an application package help you build on previous work of others? In what sense does it help you build on your own previous work? Are there graphics problems that cannot be solved by use of this application package?

   C. Give students a writing assignment to be done on a word processor. After the assignment is completed, give them another assignment requiring modification and extension of the first paper. They are building on their previous work, making use of a word processor to simplify the overall effort.

2. Computer programming.

   A. When you are writing a computer program in a language such as Logo or BASIC, in what sense are you building on the previous work of others? (Keep in mind that you are making use of a sophisticated operating system as well as a language compiler or interpreter.)

   B. An excellent sequence of programming assignments can be based on having students solve a sequence of problems, each being a relatively modest variation on or extension of the previous one. If a student's solution to the first of the problems is a carefully written, fully documented, and well-modularized program, then this solution can easily be modified to solve the second and subsequent problems. This type of sequence of assignments provides an excellent illustration of learning to do one's own work so that one can later build on it.

3. Computer awareness, including exploration of social and vocational issues.

   A. Does the four-part strategy for attacking a problem that is given in this chapter apply equally well to all disciplines? Or does it mainly favor technology-oriented problems that can be addressed by use of a computer?

B. Are most clearly defined real-world problems solvable? Or are most such problems unsolvable?

C. Does technology (such as computers) create more problems than it helps solve?

Lesson Plan 8. Attacking Hard Problems

Primary Goals

1. Students will learn a four-step strategy that can be used to attack most problems.

2. Students will learn some strategies for dealing with problems they perceive to be very difficult or perhaps unsolvable.

Prerequisites

1. (General) It is assumed that students can give examples of personally relevant problem situations that occur both in school and outside of school. Students recognize that ownership is an important part of the definition of aproblem, and students can recognize their own levels of interest, ownership, desire to reach the goal, and so forth in a problem situation.

2. (Specific) Students have a working knowledge of a formal definition of the word "problem." They have developed an initial level of skill in recognizing when a problem situation is not a clearly defined problem.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson fits comfortably into one class period. Allow students 15-20 minutes to read Chapter 4: A Four-Step Plan for Solving a Problem. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 4 contains only two new terms:

four-step plan for solving a problem
unsolvable problem

Remember that Chapter 3 contains a lot of new vocabulary. Give your students additional practice in using these terms from Chapter 3:

clearly defined problem
computer program
cooperative learning
given initial situation
goal
ownership
poorly defined problem
problem
problem posing
problem situation
resources and restrictions

Objectives

1. Students will participate in a whole-class discussion focusing on unsolvable problems that the teacher poses.

2. Students will create their own examples of unsolvable problems and will participate in a whole-class brainstorming session to create a list of unsolvable problems.

3. Students will practice using a four-step strategy that can be used to get started in attacking almost any problem.

Description

Background

A clearly defined problem has clearly defined givens, goal, resources and restrictions, and ownership. There are two major difficulties that students encounter in dealing with problem-solving situations. First, the situation is usually not a clearly defined problem. Second, many clearly defined problems are unsolvable or are beyond the capability of the student.

The four-step plan discussed in Chapter 4 can be traced back to the work of George Polya (1957). It consists of the followng four steps:

1. Understand the problem.

2. Devise a plan of action.

3. Carry out the plan.

4. Check to see if the problem is solved.

This plan allows one to approach almost any problem, whether it is solvable or not. If students apply it conscientiously and fail to solve a problem, they should then switch into a mode of what to do when a problem may be unsolvable or too difficult for their current level of knowledge and problem-solving skills. In this mode, the task may become one of posing a simpler, but closely related, problem.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is a very important idea from the previous lesson in *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Then accept several students' responses.

2. Ask students whether they feel that every clearly defined problem can be solved. Let them think about this for a minute, making arguments in their heads. (If time permits, small-group discussions leading to consensus building can be used here.) Then have the class vote yes or no on this question by a show of hands.

3. Use the vote to promote some discussion on whether every clearly defined problem is solvable. Encourage one or two students to give an example of a clearly defined problem that is not solvable.

4. Have students spend several minutes writing examples in their journals of clearly defined problems that are not solvable. Then display Chapter 4 Overhead Transparency 1: Unsolvable Problems. Do a whole-class brainstorming session to gather additional examples of unsolvable problems. For each problem that is posed, guide students through a quick mental check of whether the problem has clearly specified givens, goal, and resources and restrictions. What is there about a problem that makes it unsolvable?

5. Display Chapter 4 Overhead Transparency 2: Organize Your Thinking. Use this as an advance organizer for the remainder of the lesson.

6. Give students approximately 15 minutes to read the first part of Chapter 4 and to do the journal-writing exercise on THE PROBLEM OF A MESSY ROOM.

7. Display Chapter 4 Overhead Transparency 3: A Four-Step Plan. Discuss the four-step plan for attacking a problem. Place considerable emphasis on helping students learn to detect where or when they are not able to carry out

the steps of the plan. How can one tell when one cannot solve a problem? When should one stop working on a problem or redefine the problem to be more tractable?

8. Engage students in a whole-class discussion of how one can tell whether a problem is unsolvable or beyond one's current capabilities. Remember that persistence is a very important part of being good at solving problems. However, unthinking persistence could lead to spending a lifetime stuck on a single unsolvable problem or a problem that is beyond one's capabilities.

9. Display Chapter 4 Overhead Transparency 4: New Problems. Engage students in a whole-class brainstorming session to create examples where the steps taken to solve a problem created new problems.

10. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to finish reading Chapter 4 and to continue making regular use of their journals. Students are to do Activity 1 at the end of Chapter 4.

Student Learning Indicators

1. Formative evaluation (for the teacher).
    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words from this and previous chapters, and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
    - All students were engaged; many of them contributed in the whole-class brainstorming activities.
    - All students wrote in their journals.

Extensions and Follow-up

Have students look for examples of problems that are unsolvable. Have students ask their other teachers for examples of problems that are very difficult to solve. The students should ask their teachers how one can tell that a problem is very difficult to solve.

Notes

Problem solving is an important component of every course your students are taking. Some teachers are explicit about teaching problem solving, while others do not even mention the word "problem." In many courses the only problems presented are ones that have solutions and that can easily be solved using ideas from the course. You want your students to become aware of this and to ask their teachers, "Why?" You want them to ask, "Why do we spend most of our time dealing with relatively simple problems that are solvable? Why don't we spend more time addressing harder problems that come from the real world and may not even have a solution?"

These types of questions are often challenging. You may want to spend some time discussing them with your fellow teachers. Warn them that some of your students will be raising these types of questions in their classes.

Lesson Plan 9. Building on Previous Work

Primary Goals

1. Students will understand the importance of building on their own previous work as well as that of others when solving problems.

2. Students will understand that computers are an important aid to building on their own previous work and that of others. They also will understand that there are many other important aids.

Prerequisites

1. (General) It is assumed that students have read the first four chapters of the textbook.

2. (Specific) Students have memorized the four-step plan that can be used to attack almost any problem. They have a functional level of knowledge of the idea of a carefully defined problem and some ideas on how to move from a problem situation to a carefully defined problem.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson fits comfortably into one class period. There should be time for additional discussion of ideas from the previous lesson—particularly on unsolvable problems and what the student does when he or she encounters problems that may be unsolvable or beyond his or her current problem-solving capabilities.

Glossary

Key vocabulary and expressions from Chapter 4 include:

four-step plan for solving a problem
unsolvable problem

Objectives

1. Students will give examples of when they are building on their own previous work in solving problems.

2. Students will give examples of when they are building on the previous work of others in solving problems.

3. By building on the previous work of others, students will demonstrate an understanding of the importance of reading, writing, arithmetic, speaking, and listening in the curriculum from the point of view of problem solving.

Description

Background

Probably the single most important idea in problem solving is to learn to build on one's own previous work and on that of others. Don't repeatedly reinvent the wheel! (However, it is important to keep in mind that reinventing the wheel can be a very useful learning exercise. Such exercises help one learn to be inventive. Discovery-based education is a powerful approach to education.)

The basics of education—reading, writing, arithmetic, speaking, listening, and so forth—are "basic" because they help to build on one's own previous work and on that of others. The computer is a powerful aid to this effort. It brings a new dimension to problem solving, and it poses a very difficult question for educators:

> If a computer can solve or help solve a type of problem that we want students to learn about in school, what should we have students learn about solving this type of problem?

A question like this has no easy answer. However, it seems clear that students have the right to know that computers are useful in solving the types of problems they are studying in school. They have a right to learn the capabilities and limitations of computers as an aid to problem solving. Many educational leaders recommend that we stop teaching students to compete with computers in areas where computers are particularly useful. Instead, we should teach students to make use of computers in these areas. Perhaps one goal of computer literacy education should be to help students learn enough about computers so that they can answer this question for themselves.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall what they feel is one of the most important ideas they have learned so far from *Problem-Solving Models for Computer Literacy*. Provide a long wait time. Some students will page back through their journals or look in their textbooks. That is okay. Then accept several students' responses.

2. Ask if anyone has come up with additional good examples of unsolvable problems or if anyone has asked any of his or her teachers for an answer to an unsolvable problem. (Be especially supportive of students who have asked other teachers for examples. It is important that all teachers be involved in helping their students get better at solving problems.)

3. Display Chapter 4 Overhead Transparency 5: Horses and Wheels. Have students write in their journals on ways in which these two ideas are related. Each student is to make a list of several different ways they are related. Debrief the students after the exercise by having them share some of their ideas; record them on Overhead Transparency 5.

4. Display Chapter 4 Overhead Transparency 6: Don't Reinvent The Wheel. Do a whole-class brainstorming session on why people often communicate in parables or by using expressions such as "Don't reinvent the wheel" rather than by saying more specifically what they mean. Keep bringing the focus back to "Don't reinvent the wheel." A parable contains the essence of an important idea. But each person hearing the parable must interpret its meaning in light of his or her own world situation and the problems he or she is dealing with.

5. Display Chapter 4 Overhead Transparency 7: The Basics of Education. Do a whole-class discussion on how the basics relate to the idea "Don't reinvent the wheel." Focus the discussion on the idea that the "basics" are considered to be building blocks for helping to solve and helping to learn to solve the full range of problems one encounters in life.

6. Provide the class with time to do Activity 2 at the end of Chapter 4. In this activity students practice communicating with each other on ideas that they feel are important in the course. You want your students to gain increased ownership of the task of learning material from the course.

7. Provide the class with time to do Activity 10 at the end of Chapter 4. This focuses on how one can tell if one has produced a correct solution to a problem. If time permits, do a whole-class debriefing on this activity. It is likely that the list of responses students provide will give you an indication that our current educational system does a poor job in helping students become self-reliant problem solvers who are able to provide themselves with feedback on the correctness of the work they have done.

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 4 Overhead Transparency 8: Chapter 4 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 3, 4, 5, and 6 at the end of Chapter 4. Students are to turn these in at the beginning of the next class meeting. (Explain that the test items created in activities 3 and 4 need not be tried out on their fellow students.)

Student Learning Indicators

1. Formative evaluation (for the teacher).
   - Students were actively engaged and had fun.
   - An atmosphere of discovery-based learning was created and maintained.
   - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
   - You were satisfied with how well the class went.
   - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
   - All students were engaged; at least half of them spoke at least once.
   - All students made written notes on possible answers to the discussion questions raised in class.
   - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage your students to keep thinking about how people can tell if an answer they have produced to a problem is a correct answer. Have them raise this question in their other classes. Do some courses have more "right" answers than others?

Notes

The basics of education are very important. However, a good education is a balance between learning basics and learning to think and solve problems using the basics. The proper balance point varies from student to student. This means that students need to be involved for themselves in discovering the balance points that are appropriate to them. The proper balance point will vary from subject to subject.

The issue of "How do I know that the solution I have produced is correct?" is of utmost importance. A good part of the answer lies in having a good understanding of the process leading to a solution. Without an understanding of the process, one often cannot have much confidence in the outcome.

Additional Activities for Chapter 4

1. You know how to find the area of a square. There is a formula for it. The formula is:

   $$A = s^2$$

   A. Explain the meaning of the terms in this formula.

   B. Do you think that a student in the first grade could understand your explanation?

   This activity is designed to get students to think about the specialized notation and vocabulary they encounter in the courses they take. It could be used as the basis for a class discussion. For example, consider the formula for the surface area of a sphere:

   $$A = 4\pi r^2$$

   Some students in your class may not understand this notation. You can try to explain it to them. Or you can have those who do understand it explain it to those who do not.

2. The same type of activity can be done using the specialized vocabulary and notation from other disciplines. One goal is to help students understand that they study a subject in order to learn how to understand the problems in that subject. It is necessary to learn the vocabulary and notation in a subject to communicate with the people working in that subject and to use the reference books on that subject. That is, the vocabulary and notation have resulted from previous work of others, and one must learn them to build on that work.

3. Most real-world problems do not fit nicely into one course area. To solve a real-world problem, you may need to use knowledge from lots of different subject areas. Give an example of:

   A. A real-world problem that involves both math and history.

   B. A real-world problem that involves both science and social studies.

C. A real-world problem that involves both art and music.

This is a good class-discussion activity. It can be done as a whole-class brainstorming activity. Notice that it raises a major challenge to our educational system. If most real-world problems are interdisciplinary, why is school organized along disciplinary lines? How can we expect students to deal with interdisciplinary real-world problems when schools virtually ignore these problems?

This also brings up the topic of transfer of learning. You might begin to introduce the idea of transfer here. A whole chapter is devoted to it later in the book. How does a student transfer knowledge from school subjects to real-world problems? What can be done in school to increase transfer?

4. What happened to all of the dinosaurs that used to live on earth? There are many different theories on this. Do some library research on this topic. Find different theories that explain what happened to the dinosaurs. Which theory seems best to you? Why?

Library research is a very important part of problem solving. From very early on, students can learn to "look it up." But it is important that students learn that many problems do not have just one right answer. Many of the problems people deal with involve values and honest differences in opinion. Library research tasks should be open ended. They should be designed to help develop ownership on the part of the student.

Chapter 4 Overhead Transparency 1
Unsolvable Problems

1. **Find two positive numbers whose sum is a negative number.**
2. **Using the full resources of the planet earth, build a spaceship within the next ten years that can travel a hundred times the speed of light.**
3.
4.
5.
6.
7.

Chapter 4 Overhead Transparency 2
Organize Your Thinking

ORGANIZE YOUR THINKING

How do you get started in solving a problem that you don't know how to solve? One way is to get a clear understanding of the problem. Then devise a plan of action, carry out the plan of action, and check to see if you have solved the problem.

Some other key ideas in problem solving include:

- **Don't reinvent the wheel. Make use of previous work that you and others have done.**
- **Each school subject focuses on how to solve the problems in its subject area.**

Chapter 4 Overhead Transparency 3
A Four-Step Plan

1. **Understand the problem: This is a feeling-and-thinking step. Often you begin with a problem situation. You work on the problem situation to pose one or more clearly defined problems.**

2. **Devise a plan of action: This is a thinking step that is often done mentally with the assistance of pencil and paper.**

3. **Carry out the plan of action: This is an action step, and there is a chance of error in carrying out the actions. For some plans of action, a computer can carry out the plan.**

4. **Examine and think about the results of your work. This is a thinking step and a values step that draws on everything you know. It has two parts:**

   A. Check to see if the problem is solved.

   B. Check to see if new problems have been created.

Chapter 4 Overhead Transparency 4
New Problems

1. The solution to the problem of people needing good ground transportation led to cars, air pollution from exhaust fumes, and lots of people being killed in traffic accidents.

2.

3.

4.

5.

6.

Chapter 4 Overhead Transparency 5
Horses and Wheels

How are the following two statements related?

A. You can lead a horse to water, but you can't make it drink.

B. Don't reinvent the wheel.

1. **Both are simple statements with deep meaning.**
2.
3.
4.
5.

Chapter 4 Overhead Transparency 6
Don't Reinvent the Wheel

Think of this as a very short parable. What are some other parables?

1.

2.

3.

Why do we use parables?

1.

2.

3.

Chapter 4 Overhead Transparency 7
The Basics of Education

How do the following elements of basic education relate to the idea "Don't reinvent the wheel"?

1. **Reading**
2. **Writing**
3. **Arithmetic**
4. **Speaking**
5. **Listening**

Chapter 4 Overhead Transparency 8
Chapter 4 Summary

CHAPTER 4 SUMMARY

Many problems can be solved by following a four-step plan:

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan of action.
4. Check the results.

In devising a plan of action, it is very helpful to build on the things you already know and the things other people know. School helps you to learn the things others have already discovered about solving problems. Each school subject focuses on understanding and solving problems in one particular field.

Chapter 5. Problem-Solving Strategies Overview

Rationale and Overview

Chapter 4 provides a general four-step plan (a strategy) that can be used to attack almost any problem. It is certainly not guaranteed to succeed in producing a solution to any specific problem, because many problems have no solution and many other problems are so hard that a person is not apt to develop a solution.

Each academic discipline can be defined by the types of problems it focuses on, its collected results, its notation and vocabulary, its unsolved problems, its methodologies, and so on. Each discipline has developed or adapted problem-solving methodologies that work well within that discipline. That is, each discipline has developed strategies that are effective within that discipline.

The research on problem solving strongly suggests that there are few problem-solving strategies that are useful across all disciplines. This research talks about the roles of domain specificity in problem solving. That is, to become good at solving the problems of a discipline, one needs a great deal of knowledge about that discipline and the types of strategies used in that discipline.

However, some strategies are useful over a wide range of disciplines. These can be taught as part of almost any discipline, but they should be taught in a manner that helps increase transfer of learning. Every teacher has some responsibility to teach for transfer. Thus, all teachers have some responsibility to help students explicitly understand the problem-solving strategies they are teaching and to help students transfer possible uses of these strategies to other disciplines.

This chapter contains both a general discussion of strategies and specific instruction on several strategies that have wide applicability. Breaking big problems into smaller problems is certainly a widely applicable strategy. It is called the top-down strategy. Its success depends on eventually breaking a problem down into doable tasks (primitives). The underlying concept of this approach is that one can get better at solving problems by getting better at breaking big problems into smaller problems and by increasing one's repertoire of primitives.

The bottom-up strategy begins with things that one knows how to do, builds toward a goal or builds toward creating a goal, and then builds toward the goal one has created. One can get better at problem solving by developing an increased list of primitives and by getting better at putting them together in a manner that one finds pleasing and/or in a manner that contributes to accomplishing a task.

One reason computers are so important is that they can provide one with primitives that are easy to learn and easy to use. The square root key on a calculator provides a good example, as do graphic routines on a computer.

This chapter of the Teacher Lesson Plans contains two lesson plans. The first focuses on the general idea of a strategy and some general-purpose strategies. The second focuses on the idea of a primitive and how a calculator or a computer can give a person a greatly increased storehouse of primitives.

Coordination With Computer Literacy Courses

The idea of strategies is absolutely fundamental to problem solving. Thus, because problem solving should be a central theme in a computer literacy course, the idea of strategies should receive major attention.

The idea of a primitive—a building-block problem that one can easily solve—is also fundamental to problem solving. Access to calculators and computers greatly increases a person's repertoire of primitives.

Here are a few examples of types of questions you can explore with your class that will help relate the Chapter 5 materials to several general types of computer literacy courses.

1. Computer applications.

    A. Select an application package you know well. Describe the overall capabilities of the software. Then make a list of the primitives this software provides. For example, a graphics package might include primitives for drawing a square, for drawing a circle with a precisely defined center and radius, and for scaling a figure to a specified size. Compare/contrast having a computer make these primitives available to you versus having the primitives provided by gaining skills in the use of a combination of paper, pencil, and simple tools.

    B. Think about how long it takes to learn to use a new piece of software or some new features in a piece of software. If the human-machine interface is well designed, such learning may be natural and nearly automatic. The learning one has done on previous pieces of software or previous features of a piece of software may transfer easily to the new situation. Look for examples of application software in which this seems to be true and others where it does not seem to be true. Explore the idea that perhaps all software can be designed so that it is easily learned in a learn-by-doing, discovery-based approach.

2. Computer programming.

   A. Each computer programming language contains a very large number of primitives. Newer versions of a language may contain additional primitives. For example, early versions of BASIC did not contain graphics primitives. However, versions of BASIC for the microcomputer contain graphics primitives. Some versions of BASIC now contain graphics primitives quite a bit like the graphics primitives in Logo. Explore the question of why we have more than one programming language. Why not just build every useful primitive into one language?

   B. Select a programming language and determine how many primitives are built into the language. How many of these does one need to carry around in one's head to be a good programmer in that language? Is it necessary to have that type of memory to be a good programmer?

   C. Select two different programming languages. Make a list of at least 10 primitives that are in one and not in the other, and vice versa. Discuss the question of why all of these primitives are not in both languages.

   D. Teachers emphasize "correct" programming style in BASIC, and they emphasize top-down programming in Pascal. Logo enthusiasts emphasize bottom-up programming. However, modern computer science departments in universities teach their students both top-down and bottom-up program-design ideas and practices. Discuss these ideas with your students. When is a top-down approach most appropriate, and when is a bottom-up approach most important? How can one tell when to switch from one to the other when undertaking a major programming task? A combination of top-down and bottom-up might be called middle-out programming. Is this the way most people write programs?

3. Computer awareness, including exploration of social and vocational issues.

   A. Even a simple hand-held calculator provides some primitives. One can acquire these primitives by many hours of pencil-and-paper practice and memory work, or one can acquire them by learning to use a calculator. Is it cheating to use a calculator?

   B. More generally, there are lots of things one can learn to do by hand or that one can learn to do by using a machine. What are the social and cultural consequences of replacing "by-hand" knowledge and skills with "by-machine" knowledge and skills? What happens if the power goes off or the machines break?

C. The concept of "appropriate technology" is important in dealing with the introduction of technology into developing nations. Increasingly in our global village, developing nations must interact with the rest of the world. What constitutes appropriate computer-related technology for developing nations? How could or should computer-related technology affect education in developing nations?

D. It seems clear that the way one thinks about a problem is highly dependent on the tools and problem-solving aids one has had available as one has learned to solve problems. If one grows up using calculators and computers, one learns to think and to solve problems using these tools. Discuss the idea that if people are not introduced to these tools relatively early on in their education, they may never become fully comfortable with these tools and fully competent in using them. (Here the analogy might be with learning to speak a language like a native speaker.)

Lesson Plan 10. Strategies Useful in Many Disciplines

Primary Goals

1. Students will learn two widely applicable strategies for solving a problem: the top-down strategy and the bottom-up strategy.

2. Students will learn to recognize the strategies they commonly use in coping with problems.

Prerequisites

1. (General) It is assumed that students know that a strategy is a plan that can be used to help solve a problem. They should know that no strategy is foolproof and that some strategies are more useful than others.

2. (Specific) Students have memorized the four-step plan (the four-step strategy) for attacking problems that was presented and discussed in Chapter 4.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson is designed to fit into one class period. Allow students 15-20 minutes to read Chapter 5: Problem-Solving Strategies. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 5 contains five new terms:

bottom-up strategy
calculator primitive
computer primitive
primitive
top-down strategy

Objectives

1. Students will learn the top-down strategy; they will give examples of its use from problems they encounter in school and outside of school.

2. Students will learn the bottom-up strategy; they will give examples of its use from problems they encounter in school and outside of school.

3. Students will give examples of strategies they commonly use in coping with problem situations both in school and outside of school.

Description

Background

A strategy is a plan that can be used to attack a particular type of problem. Automatically, without conscious thought, the human mind continually develops strategies. These are often applied at a subconscious level ("I had a hunch." "I followed my intuition.")

Research on teaching problem solving provides strong support for the idea that students should specifically study strategies that are useful within specific disciplines or useful across many disciplines. The careful naming, study of, and practice in using such strategies can lead to an increase in transfer of learning. It takes a great deal of study and practice of a strategy to internalize it so that its use is automatic. This study and practice must involve a wide range of examples and occur over a long period of time.

Teaching Procedures

1. One of the assigned activities from the last class period was a journal-writing activity on SOLVING PROBLEMS USING MATH. Begin the period with a whole-class discussion on "What is math?" Make use of Chapter 5 Overhead Transparency 1: What Is Math?

   An alternative is to organize small-group discussions on this topic. Each group is to produce a list of answers to be written on butcher paper and then shared with the whole class.

   There are many possible answers, including "Whatever mathematicians do." Focus the discussion on how math is different from other disciplines. How is learning math (knowing how to do math) different from learning other disciplines or knowing how to solve the problems of other disciplines?

2. Ask students to brainstorm in their journals on some strategies they use in solving math problems. (Alternatively, have them work in small groups.) Debrief students after this activity by using Chapter 5 Overhead Transparency 2: Math Strategies.

3. Use the math-strategies discussion to get your students thinking about strategies they use in other areas. Also, help the class to analyze which of the math strategies seem to be most useful. Does the usefulness of a math problem-solving strategy change as one moves on to higher-level math courses?

4. Display Chapter 5 Overhead Transparency 3: Organize Your Thinking. Use this as an advance organizer for the remainder of the lesson.

5. Give students approximately 10-15 minutes to read the first part of Chapter 5 and to do the journal-writing exercise on STRATEGIES I USE TO HELP ME MEMORIZE THINGS.

6. Debrief students by using Chapter 5 Overhead Transparency 4: Memorization Strategies. Be aware that this activity may help your students learn some new strategies for memorization. There are many books on this subject. You might want to give your students an assignment that requires finding and reading such a book. Note that this builds on the previous work of others. People have spent years doing research on good memorization techniques. It is likely that your students have not been taught such techniques and have failed to discover them by themselves.

   You also may want to ask your students if they have ever had explicit instruction on how to memorize things. Perhaps some students have been taught memory tricks (such as use of mnemonics) and others haven't.

7. Display Chapter 5 Overhead Transparency 5: Top-Down Strategy. Discuss the top-down approach for attacking a problem. Have students contribute examples of when they personally solved a problem by breaking it into smaller pieces. You may want to have them do journal writing on this topic.

8. Display Chapter 5 Overhead Transparency 6: Bottom-Up Strategy. Discuss the bottom-up approach for attacking a problem. Have students contribute examples of when they personally solved a problem by putting together pieces, perhaps initially not even knowing where they were headed. You may want to have them do journal writing on this topic.

In discussing the top-down and bottom-up strategies, you should raise the issue of creativity. Is one of these strategies a more creative approach to problem solving? Do creative artists make more use of one strategy than the other? Do scientists make more use of one strategy than the other?

9. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to finish reading Chapter 5 and to continue making regular use of their journals. They are to do Activity 1 at the end of Chapter 5.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.

    - An atmosphere of discovery-based learning was created and maintained.

    - You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.

    - You were satisfied with how well the class went.

    - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.

    - All students wrote in their journals.

Extensions and Follow-up

Have students look for examples of strategies they use in coping with the problems they encounter outside of school. Have students look for examples of strategies they use in coping with school problems. Have students ask their teachers for good strategies. Have a "Strategy of the Day" contest. Any student can enter by writing down a strategy and posting it on the bulletin board. A team of students selects the winner. The winning strategy is written on butcher paper and posted in the front of the room until the next day's winner is selected.

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Notes

Problem solving is an important component of every course your students are taking. Some teachers are explicit about teaching problem solving, while others do not even mention the word "problem." In every course, your students learn strategies for coping with the course and for solving the types of problems that arise in the course. Sometimes these strategies are explicitly taught. In other cases, the students discover strategies for themselves. Often the strategies they discover for themselves are not very effective.

It is important to have students do metacognition on the strategies they use. It is also important for students to receive feedback on which of their strategies are relatively effective and which are relatively ineffective. This means that they must share their strategies with someone who can give such feedback or that they must learn to provide such feedback for themselves.

This is a very important idea. If time permits, you may want to spend one or more additional days on this topic. This is closely related to the ideas of Chapter 6, where we talk about more efficient and less efficient thinkers. More efficient thinkers make use of strategies that are, on average, more efficient.

You should be aware that a student's coping strategies may be deeply seated and based on early successes that have long since been forgotten. Probing the sources of a student's coping strategies can easily lead to the uncovering of psychological problems. Use extreme caution!

Lesson Plan 11. Computer-Based Primitives

Primary Goal

1. Students will understand that calculators and computers are an important source of primitives useful in solving a wide range of problems and that the availability of such primitives can have a significant impact on their personal education.

Prerequisites

1. (General) It is assumed that students have read the first five chapters of the textbook.

2. (Specific) Students understand the role strategies play in problem solving. They can name some strategies, such as top-down and bottom-up, and they can identify some of their own strategies used in coping with the problems they encounter at school and outside of school.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.
   - At least one hand-held calculator with a square root key. If possible, obtain an overhead projector calculator so that you can demonstrate calculator use to the whole class.
   - (Optional) A classroom set of hand-held calculators that have a square root key.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson fits comfortably into one class period. If you decide to make use of a classroom set of hand-held calculators, you may want to expand this lesson into two class periods.

Glossary

Key vocabulary and expressions from Chapter 5 include:

bottom-up strategy
calculator primitive
computer primitive
primitive
top-down strategy

Objectives

1. Students will give examples of some of their own primitives from several different problem-solving areas.

2. Students will demonstrate understanding of how a machine, such as a hand-held calculator, helps them to easily acquire new primitives.

3. Students will be able to explain the difference between the concept underlying a primitive and the processes needed to carry out operations to solve a primitive.

4. Students will write about some of the educational implications of acquiring primitives by learning to make use of calculators and computers.

Description

Background

The human brain has a tremendous capacity to memorize. When a problem is encountered and solved, memory traces are laid down that can help solve the problem (or a somewhat similar problem) the next time it occurs. Thus, most people soon memorize (fully automate) how to deal with a wide range of frequently occurring problems.

However, as technology has progressed and life in our society has become more complex, each of us encounters more and more problems that we have not encountered before or that we encounter only infrequently. This leads to the need for an educational system that helps us cope with infrequently occurring and unanticipated problems.

A general approach to this consists of:

1. Learning to solve a wide range of building-block problems (primitives) that are appropriate to dealing with a wide range of problems.

2. Learning strategies that can be applied to a wide range of problems.

3. Practicing using your primitives and your strategies on a wide range of problems. Developing confidence in your ability to cope with new and unexpected problem situations.

4. Learning how to learn.

Calculators and computers add a new dimension to this discussion. Of course, calculators and computers are part of the technology that is making life more complex in our society. However, at the same time they are a new source of primitives. Many problems can be solved by making appropriate use of these primitives in conjunction with mental and paper-and-pencil primitives that are traditionally acquired in school and outside of school.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to recall an example of a problem-solving strategy they have used during the past day. Provide a long wait time. Then accept several students' responses.

2. Display Chapter 5 Overhead Transparency 7: Primitives. A primitive is a building-block problem—a problem that one can solve "for sure" and can use in solving more complicated problems. Lead the class in a brainstorming effort to create a list of primitives that schools attempt to have all students acquire.

   Remember, an alternative approach is to have small-group discussions and brainstorming sessions on the topic. Each group records its results on butcher paper, and these are posted at the front of the room.

   Note that just because our schools attempt to have all students gain a particular set of primitives, this does not happen. As students progress through school, their diversity increases. You might have students do some journal-writing on the topic "Things that my teachers assume that I have learned how to do but that I don't really know how to do."

3. Discuss the idea that by learning primitives and strategies and by learning to make effective use of primitives and strategies, one can cope with a very wide range of problems. This is a deep idea—it is an underpinning of our educational system. It is often part of the answer to the question "Why do I have to learn this?"

4. Make use of one calculator or a whole-class set of calculators to discuss the idea of a calculator primitive. If you have a whole-class set of calculators, you may want to have a "contest" between calculator-equipped students and students working without calculators. Make up a set of computational exercises that can easily be done on a calculator but which are a challenge

when done by hand. Have half of the class use calculators and the other half do the exercises by hand. Compare speed and accuracy of results. The contest can be run twice using different exercises. Have students switch from using calculaors to not using calculators and vice versa.

5. Make a presentation and/or facilitate a careful discussion of the difference between understanding the concept underlying a particular problem that one might want to have as a primitiv? (such as the concept of square root) and a procedure for actually solving the problem (using by-hand methods or a machine).

6. Provide time for students to write in their journals on the difference between the concept underlying a primitive and the processes needed to actually solve a primitive. Encourage them to include several personal examples that clearly illustrate these differences.

7. The above ideas are among the most important to be covered in this text. After students have had a chance to write about the ideas, again engage the whole class in a discussion on the topic. Make use of Chapter 5 Overhead Transparency 8: Primitives—Concept and Process. Do some whole-class sharing of examples that illustrate differences between concept and process.

8. Have students work on Activity 2 at the end of Chapter 5. If time permits, also assign activities 3 and 4.

9. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 5 Overhead Transparency 9: Chapter 5 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 6, 7, and 8 at the end of Chapter 5, and turn them in at the beginning of the next class meeting.

Student Learning Indicators

1. Formative evaluation (for the teacher).

   - Students were actively engaged and had fun.

   - An atmosphere of discovery-based learning was created and maintained.

   - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.

- You were satisfied with how well the class went.

- Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; at least half of them spoke at least once.

    - All students made written notes on possible answers to the discussion questions raised in class.

    - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage your students to ask teachers in other classes for some of the building-block problems—the primitives—for the classes they teach.

Notes

Our educational system struggles with what primitives all students should acquire. For example, should all students be able to quickly and accurately spell and define a particular list of words? We have alternatives, such as providing students with a dictionary.

This, of course, raises the issue of testing. When is it appropriate to allow students to use a dictionary when taking a test? When is it appropriate to allow use of a calculator or a computer? Perhaps the simplest answer is that use of such aids to solving primitives is appropriate whenever the emphasis is on higher-order problem-solving skills. You might decide that this means that it is almost always appropriate to allow use of such aids! Some states are beginning to experiment with allowing full use of calculators, computers, and other aids to problem solving during certain types of assessment.

Additional Activities for Chapter 5

1. This activity might be good for a class discussion.

Your teacher gives you a homework assignment. The assignment is to read a chapter and to answer three questions at the end of the chapter. Here are two ways to break this homework assignment problem into several subproblems:

Approach 1

1. Read the entire chapter first.

2. Then read and attempt to answer the first question. If necessary, reread parts of the chapter.

3. Repeat step 2 for the second and third questions.

Approach 2

1. Read all three questions. Write a brief note summarizing the topic of each question.
2. Read the entire chapter. When you come to a topic that relates to one of the questions, write the page number on your notes.
3. Read and answer the first question. As necessary, reread the parts of the chapter that relate to this question.
4. Repeat step 3 for the second and third questions.

Probably you can think of lots of other ways to break down the task. In all cases the idea is to get a number of smaller problems. The specific activity is to:

A. Invent another way of breaking the task into smaller tasks.

B. Decide which of the three approaches is best for you. Explain why it is best for you.

This is a good class discussion exercise. There are lots of strategies. If the goal is to "get the right answer," one may select a strategy that often does this. But this strategy may not be good when one is faced by the goal "learn how to solve this type of problem as you work to get the right answer."

Students are smart. If a teacher places great emphasis on "get the right answer," many students will develop strategies that are useful and effective in getting the right answer. (Cheating is often effective.) But "get the right answer" is a poor goal for a teacher to set. A much more appropriate goal is "learn how to solve this type of problem as you work to get the right answer."

2. The first four chapters of this book illustrate a number of different strategies to aid in solving the problem of learning the material in the book. Each of these can serve as the basis for a class discussion or perhaps an assigned activity. Some of these strategies are given in the following list:

   1. Advance organizer. Found at the beginning of each chapter.
   2. Journaling as an aid to learning.

3. Having and/or creating a brief summary of a set of materials as an aid to learning; the summary box at the end of each chapter.

4. Draw a picture or a diagram to help you see what is happening in the problem. The human brain is very good at dealing with pictures. (Chapter 1)

5. Use brainstorming, either individually or in a group. This is a good way to get some ideas about a hard problem. (Chapter 1)

6. Make use of reference books. A good way to solve a problem is to look up how to do it in a book. (Chapter 1)

7. Set goals. (This is mentioned in a number of chapters, but perhaps the key place is Chapter 3.)

8. Metacognition is a strategy for getting better at thinking and problem solving.

3. This chapter contains an activity on strategies for memorizing. More generally, what are some good strategies for learning? This is a hard topic. What does it mean "to learn" something? One way to approach this is through the example of primitives. To learn a primitive, one needs to learn the concept and also a process. It may be very easy to learn a process, if a machine can carry out the process. But learning the concept is different. It is a mental activity, storing ideas in one's head.

   Thus, a good topic of discussion might be how to get better at learning concepts.

4. The idea of a computer primitive is very important. It is easily and powerfully illustrated in math classes. It is clear that much of the time spent in math involves teaching primitives. Math teachers estimate that 70-80 percent of the time in a math class is spent on having students learn the processes in the primitives. Only about 20-30 percent of the time is spent in learning the concepts and/or when and how to use the primitives. But a computer can do all of the processes taught in math classes. So it would be possible to make major changes in math classes. There could be a major change in how the time is used. Much less time could be devoted to learning processes. Instead, students could be given access to calculators and computers. Much more time could be devoted to concepts and when/how to use the primitives.

   This could be an excellent topic for discussion in a class. But it is a rather delicate topic. In essence, it is a criticism of our current mathematics education system! You might want to divide students into groups, choose up sides, and debate the two sides of this issue.

Chapter 5 Overhead Transparency 1
What Is Math?

1. A way of representing problems using numbers and other symbols.

2.

3.

4.

5.

6.

7.

Chapter 5 Overhead Transparency 2
Math Strategies

1. **You can usually tell if an answer is wrong if it doesn't come out a whole number or a simple fraction.**

2.

3.

4.

5.

6.

Chapter 5 Overhead Transparency 3
Organize Your Thinking

ORGANIZE YOUR THINKING

A strategy is a general plan of action for attacking a problem. Some strategies are only useful in a specific subject area or type of problem. A strategy for solving science problems might not be useful in solving sports problems. Other strategies are useful for a wide range of problems. You can get better at problem solving:

- By learning to use strategies designed to fit problems in one subject, such as math strategies and business strategies.

- By learning to use a number of strategies designed to be useful in many different problem areas.

- By learning roles of computers in making use of strategies.

Chapter 5 Overhead Transparency 4
Memorization Strategies

1. **Look at it and read it over and over again until I can visualize it in my mind. I can see it in my mind's eye.**

2.

3.

4.

5.

6.

7.

Chapter 5 Overhead Transparency 5
Top-Down Strategy

1. I do a big term paper assignment by:
    - A. Deciding on a topic.
    - B. Finding a number of sources of information.
    - C. Reading the information and keeping good notes.
    - D. Writing the paper.

2.

3.

4.

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Chapter 5 Overhead Transparency 6
Bottom-Up Strategy

1. **I decide which TV program to watch by flipping through the channels until I come to one that happens to interest me at the time.**

2.

3.

4.

5.

6.

Chapter 5 Overhead Transparency 7
Primitives

A primitive is a building-block problem—one that you can quickly, easily, and accurately solve. Thus, you can use primitives as building blocks in solving more complex, multistep problems. Examples include:

1. **Single digit addition—useful in doing larger addition problems.**

2. **Spelling words—useful in writing.**

3.

4.

5.

6.

Chapter 5 Overhead Transparency 8
Primitives—Concept and Process

1. **Communication-at-a-distance problem. I make use of a telephone. I don't know the details of building a telephone or a telephone system. I just pick up the phone and dial the number I want.**

2.

3.

4.

5.

6.

Chapter 5 Overhead Transparency 9
Chapter 5 Summary

CHAPTER 5 SUMMARY

Strategies are plans of action. They are general ways to attempt to attack a problem. Some strategies are very specialized. Other strategies can be used on a wide variety of problems.

1. The top-down and bottom-up strategies are very useful for many different problems.

2. Primitives are problems you can solve easily and accurately. You use them in the top-down strategy and in the bottom-up strategy.

3. A primitive consists of both a concept of a problem and a process for doing the problem.

4. A computer can carry out the process needed to solve many problems. If you learn the concepts of these problems, you will have acquired them as primitives.

Chapter 6. Getting Better at Thinking
Overview

Rationale and Overview

Chapter 5 focuses on strategies and primitives. It takes the point of view that you can get better at problem solving by:

1. Learning to solve a wide range of "building-block" problems (primitives) that are appropriate to dealing with a wide range of problems.

2. Learning strategies that can be applied to a wide range of problems.

3. Practicing using your primitives and your strategies on a wide range of problems and developing confidence in your ability to cope with new and unexpected problem situations.

Each of these activities is to be done at a level that requires thinking and understanding. However, the third activity particularly depends on thinking and understanding. It is relatively easy to provide students with potentially useful primitives and strategies and to have the students memorize them. It is much more difficult to help students get better at thinking while using the primitives and strategies they know.

Chapter 6 focuses on thinking and on how to get better at thinking. The underlying assumption is that all students are good at thinking. However, some are more effective (and efficient) thinkers than others. Research on thinking has led to an understanding of more effective and less effective thinking habits. We can help students to understand which of their thinking habits are relatively effective and which are relatively ineffective. We can help them increase the effectiveness of their thinking skills. This will help them become better problem solvers.

Most of what goes on in the brain occurs at a subconscious level. The brain is a very complex collection of perhaps 30-100 billion neurons. Billions of neurons may be engaged when we are "thinking about" a problem. We now have noninvasive brain scanning devices that can help us "see" brain activity and gain increased understanding of the brain activity going on when a person is thinking about a problem.

However, "What is thinking?" remains a very difficult question to answer. Much of the thinking process goes on at a subconscious level—we are not even aware that it is occurring. We know we can direct some of these subconscious activities by careful, conscious thinking efforts. We know we can automate some of these subconscious processes so that they will quickly and accurately solve certain types of problems.

There are lots of ways to improve one's thinking skills. This chapter discusses 12 ways to become a more effective thinker. These are organized into five groups. The first offers some overall considerations, such as dealing with ambiguity and learning to see other people's points of view. The remaining four groups parallel the four-step plan for attacking problems. The 12 basic ideas are widely applicable. You want to help your students to identify their strengths and weaknesses. You want your students to assume responsibility for working to improve in areas where they are relatively inefficient thinkers.

This chapter of the Teacher Lesson Plans contains two lesson plans. The first focuses on the general idea of thinking and getting better at thinking. The second focuses on 12 areas where students can understand their own levels of effectiveness through metacognition and can work to improve their levels of thinking effectiveness.

Many teachers have read Chapter 6 and provided feedback that has helped shape it. A number have commented that the chapter deals with a very delicate issue. Many students are sensitive about how well they can think—how smart they are. You should be particularly sensitive to this issue in dealing with the material in this chapter. It seems evident that some people are better thinkers than others. However, all people can improve their thinking abilities. The focus in this chapter is on self-discovery and self-improvement.

Coordination With Computer Literacy Courses

A computer is often referred to as a mechanical brain, usually with a strong hint that it is a thinking machine. The branch of computer science known as artificial intelligence aims at developing computer systems that can carry out human-like thinking processes in solving problems. Within artificial intelligence, the field of expert systems has made significant progress in recent years. This means that in some narrow domains of problem solving we are beginning to have computer programs that can compete with and perhaps outperform human experts. This raises many important issues that can be addressed in computer literacy courses.

Here are a few examples of types of questions you can explore with your class that will help relate the Chapter 6 materials to several general types of computer literacy courses.

1. Computer applications.

    A. Select an application package you know well. How "smart" is this software? That is, to what extent does this software seem to contain a great deal of knowledge as well as the ability to effectively apply this knowledge at an appropriate time?

For example, consider a spelling check that provides a list of possible alternative words when it encounters a misspelled word. What type of logic or "thinking" is built into this program? Compare two different spelling checkers on the same types of misspelled words. Do they come up with the same suggested possible correct words? What would make a spelling checker "smarter?" Would it be possible to personalize a spelling checker so that it became smarter at detecting and correcting the particular type of spelling errors a specific person makes? How could this be done?

B. Obtain an application package that makes use of some ideas from artificial intelligence. This might be an interactive conversational program, a game-playing program such as a chess player, or a program embodying ideas from the field of expert systems. Use and study the program to attempt to discover how it "thinks."

   People have been working for many years to develop chess playing programs that could compete at a world-class level. The best such programs are now able to play chess at about the same level as some people who are ranked in the upper 500 chess players in the world. One cannot play good chess by a pure-memorization approach. Rather, one must learn to make effective use of strategies. One must have primitives that can accomplish specific tasks. The best chess-playing programs effectively combine the great speed and memory capacity of computers with strategies designed to help solve the problems that arise in a chess match.

2. Computer programming.

   A. A programming language compiler or interpreter is able to detect a wide range of errors in syntax. Indeed, some compilers or interpreters even offer suggestions on how to correct the detected errors. Of course, some systems give much better error messages than others. Examine the error messages produced by the computer programming system you are using. How good are the messages? What would make them more useful? Why doesn't the computer just go ahead and correct the errors it finds?

   B. Many of the programming errors one makes are errors of logic—errors in meaning or semantics. A truly intelligent computer system would be able to detect such errors and then correct them. Discuss with your students the difficulties in developing a computer system that can detect and correct semantic errors.

This activity can be extended by having students carefully study how they go about testing and debugging a program. This self-questioning and detailed analysis is the same type of work that is done in developing expert systems.

C. Each programming language contains some aids to help programmers detect and correct errors. The aids vary tremendously from computer system to computer system. What on-line debugging aids are available in the programming language your students are using? What facilities are available in other programming systems? What facilities would you like to see added to your system?

3. Computer awareness, including exploration of social and vocational issues.

A. Within the field of expert systems there are people who have learned to do "knowledge engineering." They are skilled at interacting with a human expert in a field in order to identify and extract the methods that the human expert uses to solve problems. The expert systems now being produced are very domain-specific. That is, they function well only on very narrowly defined categories of problems. An expert system that solves medical diagnostic problems cannot solve problems dealing with where to prospect for minerals or how to recover a broken bit in a deep oil well.

Have your students explore the field of expert systems. Help them understand the capabilities and limitations of such systems. Help them begin to understand the educational implications of such systems. We now have some expert systems that can outperform the human experts who were involved in their development. It can take years of schooling and experience to get good enough to begin to compete with such expert systems. If a computer can solve or help solve a type of problem that students learn to solve in school, what should students learn about solving that type of problem?

B. Reading and writing can be thought of as an aid to human thinking. A computer is a different type of aid to human thinking. Our schools teach students to make effective use of reading and writing in solving problems rather than to compete with them. Will our schools eventually teach students to work effectively with computers rather than to compete with them? How would education change if there were considerably increased emphasis on having people work together with intelligent machines in solving problems?

C. As more and more artificially intelligent expert systems are put into place in business and industry, how will this affect employment? Will people still be able to get jobs? What types of jobs will they be able to get? In this discussion, you might point out that the machines that initially made industrial automation possible were not very intelligent. They did not contain electronic digital computers. Computers are a relatively new and powerful aid to automation and to increasing human productivity.

Lesson Plan 12. What Is Thinking?

Primary Goals

1. Students will increase their understanding of what it means "to think."

2. Students will learn that different people think in different ways.

Prerequisites

1. (General) It is assumed that students have gained some skill in doing metacognition. They have awareness of their own thinking processes and can, if they want, think critically about these thinking processes.

2. (Specific) Students know that rote memorization in useful in getting better at solving problems but that getting better at the higher-order thinking skills is essential if one is to be good at solving problems.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson is designed to fit into one class period. Allow students about 20-25 minutes to read Chapter 6: Getting Better at Thinking and to do some of the activities they encounter during this reading. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. You will notice that Chapter 6 does not contain any new terms. Use this respite to continue to practice the vocabulary introduced in the first five chapters.

You might want to think about the idea that a glossary term is a primitive. It is a building-block piece of knowledge that can be used in communication and in other problem-solving activities. In some sense, "thinking" is talking to one's self, inside one's head, using pictures and words. This self-talk requires vocabulary.

Objectives

1. Students will do metacognition and brainstorming on what it means "to think."

2. Students will examine their own levels of persistence in problem solving.

Description

Background

Thinking is a combination of conscious, purpose-directed activity and subconscious activity. Thinking is a process of carefully and consciously communicating with one's self, using words, pictures, and feelings within one's head.

Most students have not thought much about thinking. Many have little understanding about how their brains work when they are thinking and how to make more effective use of their brains' thinking powers. Many do not realize that different people think in different ways, or that some approaches to thinking may be more effective than others.

All students can become more effective and more efficient thinkers.

Teaching Procedures

1. Begin by displaying Chapter 6 Overhead Transparency 1: Organize Your Thinking. Tell your class that the focus will be on thinking about thinking about what thinking is.

2. Ask your class to do a group brainstorm session to make a list of people who were (or still are) good thinkers. Make use of Chapter 6 Overhead Transparency 2: Good Thinkers.

   After a reasonable list is created, ask your class for common characteristics of the group. What does a person have to do to be considered a good thinker? Do we recognize good thinkers only by the activities they do, the problems they solve, and so on? Are there many equally good thinkers who are not on the list?

2. Give students 15-20 minutes to read the first part of Chapter 6 and to complete the journal-writing and discussion activity WHAT DOES THE WORD "THINK" MEAN?

You may want to provide each small discussion group with a piece of butcher paper and have each group write its definition of the word "think." Post these in the front of the room and use them as a basis for class discussion.

4. Have students share some of their definitions of "think." You want the discussion to bring out the idea that different people think in different ways. Some people think in words—they talk silently to themselves. Others think is pictures—they make a motion picture in their heads. Still others may think with their whole bodies—a type of kinesthetic thinking. Your students may talk about intuitions and feelings. Perhaps intuitions and feelings are produced at the subconscious level and are then transmitted to the conscious brain.

5. Give students time to finish reading the chapter and to do activities 1 and 2 at the end of the chapter. The next lesson plan focuses on 12 ideas for becoming more effective at thinking. It will help if students have read these ideas and begun to think about them.

6. Raise the issue of persistence as being an important part of problem solving. Discuss this very briefly, indicating that persistence is an important part of thinking. Use the example of Edison, who indicated that his success was due mainly to persistence.

   Have your students do a mental exercise of thinking about someone they know who is very persistent and someone else they know who is not persistent. All students are to introspect on their own levels of persistence. Are they satisfied with their own levels of persistence? If not, what could they do to change their levels of persistence? If time permits, have students write about this in their journals.

7. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to ask at least two different people to define "to think." They are to write a short report on how these results compare with the definitions produced in their small-group and whole-class discussions.

Student Learning Indicators

1. Formative evaluation (for the teacher).

   - Students were actively engaged and had fun.

- An atmosphere of discovery-based learning was created and maintained.

- You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.

- You were satisfied with how well the class went.

- Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.

    - All students wrote in their journals.

Extensions and Follow-up

Have students think about who are the very best thinkers they know and who are some not-so-good thinkers they know. In what ways are these people the same and in what ways are they different?

This can be made into a knowledge-engineering activity. What are the characteristics of good thinkers? The chapter contains a list of characteristics, but this list might be totally inappropriate or inadequate in the eyes of your students. Set them to work individually or in groups to come up with an appropriate and useful list of characteristics of good thinkers.

Notes

Every student in your class is a good thinker. However, some are better thinkers than others. Every student can become a better, more efficient, more effective thinker. One of your goals as a teacher is to help your students to become better thinkers.

However, thinking and ways of thinking are very personal things. Thus, it is important that all of your students learn how their minds work—how they think. They need to decide for themselves whether they are satisfied with how they think and whether they want to improve some aspects of their thinking processes. Ownership is essential here!

Lesson Plan 13. Effective Thinking Practices

Primary Goal

1. Students will understand that some thinking practices are more effective and efficient than others.

2. Students will gain increased skill in recognizing some of their more effective/efficient and less effective/efficient thinking practices and will learn ways to improve their thinking skills.

Prerequisites

1. (General) It is assumed that students have read the first six chapters of the textbook.

2. (Specific) Students understand the role strategies play in problem solving. They can name some strategies, such as top-down and bottom-up, and they can identify some of their own strategies used in coping with the problems they encounter at school and outside of school. This lesson focuses on some strategies for becoming a more effective and efficient thinker.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson can be done in one class period. However, it can easily be expanded to two or more class periods. To do this, just expand the time spent on each of the 12 main ideas of what constitutes an "effective/efficient" thinker.

Glossary

No new terms are introduced in Chapter 6. Remember that it is very important to make frequent use of the new vocabulary introduced in this book. As students internalize this vocabulary, they will be able to communicate more effectively with themselves and others about problem solving and thinking.

Objectives

1. Students will give examples of more effective/efficient and less effective/efficient thinking.

2. Students will identify some of their own areas or types of more effective/efficient and less effective/efficient thinking.

3. Students will identify and practice actions designed to help them become better thinkers.

Description

Background

Every student in your classes is a relatively efficient, effective, and successful thinker. However, some are more efficient, effective, and successful than others.

Research strongly supports the contention that through proper training and experience every person can get better at thinking. (Indeed, this is a fundamental supposition of our school system.) This training and experience should be built into every aspect of education. However, it is also helpful to specifically identify, name, and categorize types of thinking activities. Research has proven the effectiveness of giving students specific instruction in identifying their own areas of relative strength and relative weakness and of providing them with help in working on their areas of relative weakness.

You and your students should not expect magical, overnight success in becoming better thinkers. Lifelong habits are difficult to change. However, they can be changed by a careful, conscious effort applied over a significant period of time. The lesson given here is merely a starting point.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to share very brief definitions of what it means "to think." Then have students think about some good thinking they have done in the past day. Student are to spend a couple of minutes writing in their journals about the nature of this thinking and what it accomplished. Part of the focus should be on how it felt to do good thinking.

2. Display Chapter 6 Overhead Transparency 3: Getting More Effective and Efficient. Lead the class in a brainstorming effort to identify areas of human

endeavor in which study and practice leads one to become more effective and/or efficient.

Help your students to understand what it means to be "more effective" and to recognize the possible benefits of this effectiveness. For example, a student might say, "I have learned a strategy for memorizing a list; when I use this strategy, I can remember the list much better."

Help your students to understand what it means to be "more efficient" and to recognize the possible benefits of this efficiency. For example, a student might say, "I am more efficient at making my bed than I used to be. I can do it in about two minutes now, and it used to take about five minutes to make it look the way I like it to look." Here, efficiency refers to use of time. There are other ways to think about efficiency. A painter may think about efficiency in terms of using fewer brush strokes or a less cluttered design.

Remember that an alternative approach is to have small-group discussions and brainstorming sessions on the topic. Each group records its results on butcher paper, and these are posted at the front of the room.

Use the exercise to get students thinking and talking about effectiveness and efficiency of thinking. A more effective, efficient thinker can do more and do better in less time. A person can get to be a more effective, efficient thinker by study and practice.

3. Display Chapter 6 Overhead Transparency 4: Some Thinking Habits. Overheads 4-8 contain lists of important thinking habits. For each of the overheads, you want your students to identify their own strengths and weaknesses. You want them to accept ownership and personal responsibility for their own habits. You want them to learn that it is possible to change their habits.

   One way to do this is to display and briefly discuss a thinking habit, such as Dealing With a Lack of Clarity, the first item in Chapter 6 Overhead Transparency 4: Some Thinking Habits.

   Brainstorm with the class on more effective/efficient and less effective/efficient ways to deal with a lack of clarity. Then have your students write in their journals. They are to do a self-evaluation on how they deal with a lack of clarity. They are to identify specific instances in which they dealt effectively/efficiently with a lack of clarity and other instances in which they dealt less effectively/efficiently with a lack of clarity.

   If you take this approach, it will take at least 15-20 minutes to cover each of the 12 thinking habits discussed in Chapter 6. Thus, this lesson will be expanded into a number of lessons.

The particular approach you take may depend on the nature of the course you are teaching. If it is a general course on problem solving, you will want to devote a great deal of time to this chapter. If it is a course mainly focusing on roles of computers in problem solving, you will want to devote less time to this chapter.

4. As time permits, debrief students after the discussion and/or the class activity for each of the thinking habits. The debriefing might cover a wide range of topics, such as how thinking habits are developed, how they can be changed, what role schools can play in helping students to change their thinking habits, and so on.

5. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 6 Overhead Transparency 9: Chapter 6 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 7 and 8 at the end of Chapter 6 and turn them in at the beginning of the next class meeting. Activity 8 is one that a student may want to continue to work on for several weeks. Encourage your students to do daily journal writing for a week or more on the thinking habit they identified in Activity 8.

Student Learning Indicators

1. Formative evaluation (for the teacher).
    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
    - All students were engaged; at least half of them spoke at least once.
    - All students made written notes on possible answers to the discussion questions raised in class.

- All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

Encourage your students to pay attention to their other problem-solving and thinking habits. They are to identify effective, efficient, productive habits and less effective, efficient, productive habits. They are to develop a plan for self-improvement.

Notes

It is difficult to change one's habits. How many times have you made a New Year's resolution to change a habit? How many times have you been successful in accomplishing your resolution?

However, you are aware of changes you have been able to make in your habits. All people can change their habits. Some can do so with little external help, while others require a lot of help, encouragement, and support. Help your students to understand that they can take increased responsibility for themselves and how they function.

Additional Activities for Chapter 6

1. Can a cat think? How do we know? Can a fish think? How do we know? Can a fly think? How do we know? Can an elevator think? How do we know? Can a hand-held calculator think? How do we know? Can a computer think? How do we know?

   This is a metacognition exercise. It can be done as a homework assignment, or it could be used to promote class discussion. It seems clear that different living creatures have different levels of brain power or thinking ability. We can place different animals on an "ability to think" scale. Can we do the same thing for machines? Or is it a completely ridiculous idea to think of these scales as being similar?

   This is a very deep question. The living creature is self-replicating. Much of the self-replication process occurs at a subconscious, instinctive level. Does the scale we use for living creatures overlap with the scale we use for machines? For example, is the "smartest" computer as smart as the least smart living creature?

2. Hand out a test you have used in a course. (Or if you prefer, hand out a sample of a standardized test.) The goal is to have students analyze the test from a "thinking" point of view. Which questions seem to require a lot of thinking? Which questions seem to require little or no thinking? Could a computer program be developed that could do well on this type of test?

This is a good activity to use to start a class discussion. Some test questions test thinking. Other test questions test memorization. Both thinking and memorization are important.

How can you test for understanding of a concept? (This relates to the concept-and-process ideas in a primitive.) A good activity here is test-question posing. Pick a primitive that students in your class know. Ask them to create test questions that get at the concept. Ask them to create test questions that get at a process for solving the primitive. Emphasize that testing understanding of a concept tends to be a test of thinking.

3. The Cardinal edition of the *Merriam-Webster Pocket Dictionary*, contains the following definition for "think":

think

1. To form in the mind; to have in, or call to, the mind the notion or image of something; to imagine.
2. To have an opinion of something; to believe.
3. To reason.

Compare and contrast this definition with the definition you developed by brainstorming in small groups and/or by the whole-class discussion on this topic.

Chapter 6 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

This chapter discusses a number of things you can do to get better at thinking. As you get better at thinking, you will get better at solving problems. To get better at thinking:

- Learn what more effective thinkers do.
- Understand your own more effective thinking-skill habits and your less effective thinking-skill habits.
- Develop more effective thinking-skill habits and practice them.

Chapter 6 Overhead Transparency 2
Good Thinkers

1. **Marie Curie**

2. **Albert Einstein**

3.

4.

5.

6.

7.

Chapter 6 Overhead Transparency 3
Getting More Effective and Efficient

1. **I am getting more effective and efficient at brushing my teeth. I brush faster; I get them a lot cleaner.**

2.

3.

4.

5.

6.

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Chapter 6 Overhead Transparency 4
Some Thinking Habits

General Considerations

1. **Dealing With a Lack of Clarity**

2. **Seeing Others' Points of View**

3. **Valuing Education and Good Thinking**

4. **Attitude and Self-Confidence**

Chapter 6 Overhead Transparency 5
Some Thinking Habits

Understand the Problem: Developing Goals

5. Search for Goals

6. Revising Goals

Chapter 6 Overhead Transparency 6
Some Thinking Habits

Understand the Problem: Resources and Restrictions

7. Resources

8. Restrictions

Chapter 6 Overhead Transparency 7
Some Thinking Habits

Evaluating Possible Different Plans

9. **Finding and Using Evidence**

10. **Anticipating Outcomes**

Chapter 6 Overhead Transparency 8
Some Thinking Habits

Is the Problem Solved?

11. Have I Solved the Problem?

12. Unexpected Side Effects

Chapter 6 Overhead Transparency 9
Chapter 6 Summary

CHAPTER 6 SUMMARY

One way to get better at solving problems is to get better at thinking. More effective and efficient thinkers make better use of their brains. They have a number of thinking-skill habits that relate to the steps one follows in solving problems. Some very important good-thinking habits include:

1. **Valuing education and working to get a good education.**
2. **Having good skills in developing and revising goals.**
3. **Having good skills in developing resources and in knowing appropriate restrictions.**
4. **Being good at thinking about possible outcomes from carrying out a plan of action.**

You can become a better thinker and problem solver if you will identify your less effective/efficient thinking habits and consciously work to improve them.

Chapter 7. Transfer of Learning Overview

Rationale and Overview

Chapter 6 focuses on thinking and on good thinking habits. Good thinking habits are useful in attacking problems in many different disciplines. That is, they *transfer* from one discipline to another.

Such transfer of learning, or of problem-solving habits, occurs more readily for some students than for others. Also, it may occur more readily in one situation than in another. For example, a student may have a good attitude and good self-confidence in dealing with one type of problem but not in dealing with another type of problem.

There is a great deal known about transfer of learning, and it is a field of active research. Still, transfer of learning remains a difficult topic.

The classical approach to discussing transfer of learning is to talk about near transfer and far transfer. The idea here is that in some sense two tasks or types of problems are "near" to each other or "far" from each other. Suppose that two tasks or problems are near to each other. Then we expect that a student who has learned how to accomplish one of the tasks, or solve one of the problems, can readily transfer the needed knowledge and skills to the other task or problem. You have learned how to tie your left shoe when it has a new, brown, cotton shoelace. Most likely you can tie a right shoe that has an old, white, nylon shoelace. Clearly these are not the same problem. However, they are "nearly" alike.

The human brain is designed to easily deal with situations that are nearly alike. Human memory is an intricate pattern-matching system. The brain recognizes when the neural patterns of a new situation are nearly the same as the neural patterns of a previously encountered situation. Without conscious thought, it automatically deals with the new situation by using a previously learned methodology.

Unfortunately, this general description and model for transfer begins to be less useful as we examine more complex tasks and as we compare different students. In multistep problem-solving situations, it is necessary for the brain to recognize a sequence of patterns. Careful, conscious thought may be needed to direct the brain in this process. The research indicates that the nearness or farness of a transfer is highly dependent on the individual attempting to do the transfer. What one student accomplishes without conscious thought by a near transfer may prove impossible for another student who has had approximately the same training and experience.

In recent years, a number of theories of transfer of learning have been developed. This increasing level of knowledge about learning theory can provide a basis for improvement in teaching methodology and in how students approach learning. A very brief summary of current knowledge about transfer of learning includes the following points:

1. Every student transfers learning, but not all students are equally good at transferring learning. (Indeed, one measure of intelligence is how readily and how far a student transfers knowledge.)

2. The ability for a student to transfer a particular learning episode to other situations is highly dependent on the particular student.

3. Transfer can be increased by specific instruction designed to increase transfer and by having students carry out activities designed to increase transfer.

4. It is possible to teach for automaticity of transfer. Many of the processes involved in driving a car and other vehicles provide appropriate examples. One's automatic typing skills easily transfer among different computer keyboards.

5. It is possible to teach for careful, conscious, reasoned transfer. As an example of this, a student can learn the top-down strategy of breaking big problems into smaller problems. The student can learn to verbalize this strategy and can practice using it in a wide variety of situations. The student can learn that this strategy is likely to be useful in dealing with almost any new complex problem that is encountered. This type of problem-solving knowledge is apt to transfer to new problems a student encounters.

This chapter continues to take the approach that students need to have vocabulary that allows them to talk about and think about the ideas they are to learn. You don't have to be a graduate student to talk about near transfer and far transfer. You don't have to be a graduate student to begin to take responsibility for your own learning and how well this learning transfers. Indeed, we know that even grade school students can do this with proper instruction and guidance.

Chapter 7 focuses on transfer of learning and how to get better at transfer of learning. It discusses near and far transfer. It discusses some brain theory that can help one understand transfer and possibly how to increase transfer. (One can increase transfer by building richer or more varied neural connections among the areas where one wants to transfer knowledge and skills.)

Chapter 7 places considerable emphasis on the difference between understanding a concept and understanding a process to carry out the ideas underlying the concept. For example, the concept of a circle graph is used to represent data that helps solve a problem. This is different than knowing the details of how to take data and use paper, pencil, protractor, and compass to produce a circle graph.

Both concept and process are important. Both take time and effort to learn. Both may transfer to other situations. However, suppose the goal is to learn to use a circle graph to solve problems in a wide variety of settings. Specific instruction and practice in using a circle graph in a wide variety of settings will contribute more to this transfer than will lots of practice in drawing circle graphs by hand. However, lots of practice in drawing circle graphs by hand may transfer to other tasks that involve manual dexterity and use of pencil, paper, protractor, and compass. Thus, it is important to give careful consideration to what one wants to transfer.

We can teach for the understanding and applicability of concepts, and we can teach for knowing how to carry out the steps in a process underlying a concept. It is here that computers are bringing a new dimension to education. In many instances a computer can carry out the steps in a process that underlies a concept. A computer can produce a circle graph. It may take only a few minutes to learn how to have a computer produce a circle graph.

This is a very important idea. To "know" something, such as a circle graph, one needs to know both the concept and an underlying process. In many instances the underlying process can be done by hand or by using very simple machines, such as pencil, paper, protractor, and compass. It may take a great deal of training and experience to learn to do implementations of a process by hand. Alternatively, we may make use of more complex machines, such as a calculator and computer. Then it may take only a modest number of minutes to learn to carry out a particular process.

This chapter of the Teacher Lesson Plans contains two lesson plans. The first focuses on the general idea of transfer of learning and on near and far transfer. This ties in nicely with some of the ideas on increasing effectiveness and efficiency of thinking discussed in Chapter 6. The second lesson focuses on ways to increase transfer of learning. It also touches on the idea that certain types of tests encourage certain types of learning. If we want students to put learning energies into activities that promote far transfer, we need to design tests that reward far transfer.

Coordination With Computer Literacy Courses

One of the main goals in a computer literacy course is for the student to gain general knowledge, attitudes, and skills that will be useful in other courses and in life outside of school. Thus, transfer of learning is very important. Teaching should be designed to promote transfer.

Here are a few examples of types of questions you can explore with your class that will help relate Chapter 7 materials to several general types of computer literacy courses.

1. Computer applications.

   A. Select two different versions/models/brands of a particular software application package, such as a word processor. One should be selected because your students have learned to use it. The other should be new to them. Give your students a chance to learn to use the new software on their own; provide them with little or no instruction. Help them to understand that the learning they have done easily transfers to the new software. Use this as a basis for discussing transfer of learning and the roles a computer can play in helping to make transfer easier.

   B. In what ways are all computers alike? In what ways are they different? What knowledge about using a computer readily transfers to using other computers? What changes to computer hardware and software design would help in increasing transfer?

   C. Suppose you have learned to solve a particular type of problem by hand, perhaps by organizing data into a card-file database or organizing financial information into a table. To what extent does this knowledge transfer to using a computer to solve the same types of problems?

   Most of the problem-solving ideas in this book do not depend on having computers available for use. A person who is a good at solving problems without the use of computers can make very rapid progress in learning to make effective use of computers as an aid to solving problems.

2. Computer programming.

   A. All computer programming languages have certain features in common. Thus, consciously learning to understand, name, and talk about these features can be helpful in learning a second or third programming language. Data structures, control structures, and error messages provide excellent examples. Examine how you teach computer programming and what your students are learning. Are they being taught in a manner that promotes their learning other programming languages? What could be done to increase the ease of transfer of their learning to other programming languages?

   B. One way to increase transfer of learning in programming would be to have just a very small number of programming languages—to have the data structure, control structure, error messages, data types, and so forth in all languages be nearly the same and to make every version of a particular language as nearly alike as possible. Why hasn't this occurred? Is the diversity in programming languages good or bad for the field of computer science?

3. Computer awareness, including exploration of social and vocational issues.

   A. Our society has moved from the agricultural era to the industrial era to the information era. Suppose one studies the change process and its effects as a society moves from an agricultural era to an industrial era. To what extent does the resulting knowledge and understanding transfer to the situation of a society moving from an industrial era to an information era? Is there a methodology for studying societies as they move from one era to another that transfers to the study of any such societal movement?

   B. Is is possible to learn how to learn? To what extent do you emphasize learning to learn in your teaching? Do you make some particular aspects of learning to learn particularly explicit so as to increase the likelihood of transfer to other learning situations?

   C. Explore with your students their ideas on transfer of learning among major categories of courses they take. Do some of your students readily transfer knowledge among their science courses but not transfer this knowledge to social science or fine arts courses? Do some of your students transfer ideas from their music courses to social science and science courses?

   D. Transfer of learning is usually considered to be a process whereby a person takes knowledge and skills learned in one situation and applies them in another. Teaching can be thought of as a process whereby knowledge and skills acquired by many people are "transferred" to students. One way to do this is to build the knowledge and skills into machines and merely teach the students to use the machines. Discuss this view of transfer.

   E. Computers can be used to help score and help analyze objective tests. To what extent is our educational system being driven by such objective tests? Do these tests do an adequate job of measuring higher-order thinking skills and encouraging teaching/learning for transfer?

Lesson Plan 14. Near and Far Transfer

Primary Goals

1. Students will learn the meaning of transfer of learning.

2. Students will learn that they do both near and far transfer and that both are important in building on their previous learning.

Prerequisites

1. (General) It is assumed that all students have an intuitive understanding of transfer of learning. They can cite examples of when they have transferred knowledge and skills gained in one problem-solving situation to a different problem-solving situation.

2. (Specific) Students have read Chapter 6 on effective/efficient thinking habits and are consciously aware of when they make use of these habits in a variety of different thinking situations.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson is designed to fit into one class period. It contains some follow-up of the previous lesson on thinking habits. Allow students about 15 minutes to read Chapter 7: Transfer of Learning and to do some of the activities they encounter during this reading. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 7 contains three new terms:

far transfer situation
learning theory
near transfer situation

Objectives

1. Students will give personal examples of near and far transfer.

2. Students will give examples of when they have made use of one of their more effective and/or efficient thinking habits in several different settings.

3. For one class period, students will pay careful attention to ideas that might transfer into or out of that class.

Description

Background

One of the most important ideas in problem solving is building on your previous work. This is closely related to transfer of learning. If you can transfer your learning from one setting to another, you are building on your previous learning efforts.

All students do both near and far transfer. All students can get better at near and far transfer. Teaching and learning for transfer can increase near and far transfer.

Teaching Procedures

1. Begin by displaying Chapter 7 Overhead Transparency 1: Organize Your Thinking. Tell your class that today the focus will be on a subject called learning theory. Explain that in the "good old days" only university graduate students got to study transfer of learning. Now, they are getting a chance to do so because it will help them to make more effective and efficient use of their schooling.

2. Ask your students to think about one of their most effective and/or efficient thinking habits. (Remind them of the thinking habits discussed in Chapter 6.) Students are to spend time writing in their journals about this thinking habit. They are to give several different examples of when they have used this thinking habit.

3. Debrief the students by pointing out that they had to learn the thinking habit at some time and some place. Now, they transfer this learning to other situations.

4. Display Chapter 7 Overhead Transparency 2: Near and Far Transfer. Facilitate a discussion on the ideas of near and far transfer. Students are to give personal examples of near and far transfer.

   You may want to do this activity in small discussion groups. Provide each small discussion group with a piece of butcher paper and have each group write good examples of near transfer and of far transfer. Encourage group discussion on whether something that is near transfer for one person is near transfer for all people in the group. Post the group results in the front of the room and use them as a basis for class discussion.

5. Give your students about 10-15 minutes to read Chapter 7.

6. Discuss the text's ideas on brain theory with your class. The neurons in one's brain are massively interconnected. The process of learning something is a process of building neural interconnections and the strength of these connections. Display Chapter 7 Overhead Transparency 3: Everything Is Connected. Give your students practice in finding connections in their own brains between relatively unrelated ideas and events. You can do this as a journal-writing activity or as a "stream of consciousness" oral activity, with different class members volunteering to participate.

7. If time permits, have students do the following activity as a journal-writing exercise. (This is from the Additional Activities section of the lesson plans for Chapter 7.)

   Open a dictionary at random and write down the first noun you come to. Next, open to a different page and write down another noun from that page. Finally, write down some connections between these two nouns. How are they alike? How are they different? Do they both relate to something that you know?

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to select one class (for example, next period's class). During that class they are to pay careful attention to ideas that could transfer into that class from other classes and ideas that could transfer out of that class into other classes. They are to make a list of these ideas and to turn in the list as homework.

Student Learning Indicators

1. Formative evaluation (for the teacher).
   - Students were actively engaged and had fun.
   - An atmosphere of discovery-based learning was created and maintained.
   - You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.
   - You were satisfied with how well the class went.
   - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
   - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.
   - All students wrote in their journals.

Extensions and Follow-up

Have students think about and talk about whether what they learn at school is relevant to life outside of school, and vice versa. Encourage them to look for examples of transfer of learning between these two different learning environments.

Notes

As a teacher, you may want to pay more attention to your own transfer of learning. How often do you bring ideas you have recently learned outside of school into your teaching? How often do you make use of what you are teaching to help you deal with problem situations outside of school?

Lesson Plan 15. Increasing Transfer of Learning

Primary Goal

1. Students will understand that transfer of learning can be increased.

2. Students will learn some specific ways to increase their own transfer of learning.

Prerequisites

1. (General) It is assumed that students have read the first seven chapters of the textbook.

2. (Specific) Students can give specific examples of some of their thinking-skill habits that they use in a variety of settings.

Materials Setup

1. (For the teacher)
   - Overhead projector, blank acetate, acetate pens.
   - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
   - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson is designed to be done in one class period.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 7 contains three new terms:

far transfer situation
learning theory
near transfer situation

Objectives

1. Students will give examples of what a teacher can do to help them increase transfer of learning.

2. Students will give examples of what they can do to help themselves increase transfer of learning.

3. Students will identify and practice one specific approach to increasing their own transfer of learning.

Description

Background

As we have said several times in this book, "You can lead a horse to water, but you can't make it drink." Learning and transfer of learning are personal things. School can provide an environment that encourages and facilitates learning and transfer of learning. But a school cannot do the learning for a student.

Research indicates that we can teach in a manner that encourages and aids transfer of learning. One way to do this is to make students consciously aware of the need for and value of transfer. Another way is to help students to develop their own particular ways that will help them to increase transfer. This lesson focuses on these approaches.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to share examples of knowledge and skills from one class they are taking that can be used in another class they are taking. Then ask for examples of what teachers do to encourage this type of transfer. (Here you are looking only for positive examples. You are not soliciting comments about teachers who don't seem to encourage such transfer.)

2. Display Chapter 7 Overhead Transparency 4: Learning for Near Transfer. Lead the class in a brainstorming activity that identifies a number of examples of Type 1 Learning, which focuses mainly on near transfer. The underlying idea is that of stimulus-response, with quick and automatic recall or response.

   Remember that an alternative approach is to have small-group discussions and brainstorming sessions on the topic. Each group records its results on butcher paper, and these are posted at the front of the room.

   Use the exercise to get students thinking about and talking about Type 1 Learning. When is it appropriate, and why?

3. Display Chapter 7 Overhead Transparency 5: Learning for Far Transfer. Lead the class in a brainstorming activity designed to produce examples of Type 2 Learning. Here the focus is on rich and varied neural connections. There is no "right" answer; the point is to build connections with other ideas that are personally important. The latter point is of extreme importance. Learning is personal. The neural connections that are built must tie in with what one already knows and with what one already considers to be important. An emotional connection, such as "I cried when our cat ran away," can be a very important connection when studying household cats.

4. Display Chapter 7 Overhead Transparency 6: What Teachers Can Do to Help Increase Far Transfer. Solicit your students' perceptions of what their teachers do that might help them to increase transfer. Your students' comments will give you insight into what you and other teachers are doing. Don't be defensive!

   Notice the two examples provided on the overhead. Both focus on testing. Research strongly supports the idea that students adjust to the testing situation. If teachers give tests that focus on lower-order thinking skills, students will study for such tests and will get better at lower-order thinking skills. If teachers give tests that require higher-order thinking skills, students will get better at higher-order thinking skills.

   Most teachers create tests that focus on Type 1 Learning. Gradually their students learn that being educated means to having memorized a large number of facts that one can regurgitate at an appropriate time. There are substantial differences among the educational systems of different countries, with some countries focusing very strongly on rote memorization.

5. Display Chapter 7 Overhead Transparency 7: What Students Can Do to Help Increase Their Own Far Transfer. This activity is best done as a journal-writing activity. All students are to brainstorm on what works best for them. They might do this for a particular subject, or they might do this for all the subjects they are studying. The goal is for students to increase their awareness of what works for them.

6. If time permits, have students do activities 3 and 4 at the end of the chapter. Remind students that higher-order thinking skill questions encourage drawing on one's total and personal knowledge rather than just interrelating ideas presented in class.

7. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 7 Overhead Transparency 8: Chapter 7 Summary. Each student is to decide on one idea he or she felt was particularly

important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to select one course they are taking. For several class sessions they are to make a list of the most important ideas that are presented. For each idea they are to do free association—brainstorming of related ideas. They are also to pay attention to related ideas that occur in other courses they are taking. All of this is to be done in writing and turned in as a written assignment.

Student Learning Indicators

1. Formative evaluation (for the teacher).
    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
    - All students were engaged; at least half of them spoke at least once.
    - All students made written notes on possible answers to the discussion questions raised in class.
    - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

It is often suggested that the educational system in the United States is "run by" the testing services that create and disseminate machine-scored, standardized tests. Your students could carry out a major project by examining the extent to which such tests impact their school and school district. This study should also emphasize looking for alternatives. What problem situation is addressed by standardized tests and what are some alternative approaches to dealing with this problem situation?

Notes

We know a great deal about teaching for transfer. Unfortunately, many teachers, as well as the overall design of many school systems, encourage Type 1 learning that does not readily transfer. You can encourage your students to develop learning habits that promote transfer of learning. However, you need to be aware that significant parts of our current educational system actually tend to discourage this type of learning.

As your students gain better understanding of lower-order and higher-order skills, and as they relate this to teaching for near and far transfer, they may begin to challenge some teachers. You will want to discuss this possibility openly in your school. Use this as an opportunity to make a major change in how your school approaches learning and testing!

Additional Activities for Chapter 7

1. Make a list of things you can do to increase your transfer of learning. Make a list of things that your teachers could do to help you increase transfer of learning.

   Transfer of learning is one of the most important ideas in helping students to get better at solving problems. One measure of "intelligence" is how easily a person does such transfer. A more "intelligent" person seems to be able to make far transfers more easily than other people. But we can teach for transfer. We can help students to increase their ability to do far transfer. Thus, we can help students to become more "intelligent."

2. Open a dictionary at random and write down the first noun you come to. Next, open to a different page and write down another noun from that page. Finally, write down some connections between these two nouns. How are they alike? How are they different? Do they both relate to something that you know?

   This type of activity helps to train the brain to do far transfer. In the brain, everything is related to (connected to) everything else. But often the connection is rather tenuous. It is interesting to see the connections one comes up with in this type of activity.

   This activity can be used in a whole-class discussion. Have a student give a new word from one of the classes he or she is taking. Then have another student give a word from a different class. Ask students to give connections between the words. To what extent do most people in the class come up with the same connections? Is this commonality of connections a product of students having a lot in common?

3. What is a metaphor? Look up the word in a dictionary. How does it relate to near and far transfer?

4. Name two sports that are alike. How are they alike? How are they different?

   Now get together with another student in your class. Exchange a list of two sports each of you name. Make a list of how you think/feel the other student's two sports are alike. Then compare your list with the other student's list.

5. Which of the courses you take make use of essay tests? Which make use of open-book tests? Which make extensive use of objective tests? Which don't have tests? Relate your answers to how this helps you to learn and your perceptions of the value of the courses to you.

6. How do you study for an objective test? How do you study for an open-book test? How do you study for an essay test? Relate your answers to Type 1 and Type 2 learning.

Chapter 7 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

Learning is a way to prepare for the future. You can learn about a type of problem situation at one time and place. You can then use this knowledge to deal with a problem situation at a different time and place. When the two problem situations seem nearly the same to you, this is called a "near transfer" situation. When the two problem situations do not seem much alike to you, it is called a "far transfer" situation.

- **Near transfer is easy. Your mind does it automatically, with little conscious thought.**
- **Far transfer is harder. You can get better at far transfer by study and practice. Getting better at far transfer will make you a more efficient learner.**

Chapter 7 Overhead Transparency 2
Near and Far Transfer

Near Transfer Situations:

1. Tying a new pair of shoes after learning to tie an old pair of shoes.

2.

3.

4.

Far Transfer Situations:

1. Trying to tie a bow tie after learning to tie a bow in shoelaces.

2.

3.

4.

Chapter 7 Overhead Transparency 3
Everything Is Connected

I think that I shall never see
A poem as lovely as a tree.

(In Joyce Kilmer's mind, a poem and a tree are related because they are both lovely.)

Here are some words or ideas. How are they related in your mind?

1. **A house and the earth.**
2. **An ocean and a cup.**
3. **Art and math.**
4. **Dogs and cats.**

Chapter 7 Overhead Transparency 4
Learning for Near Transfer

Type 1 Learning—Learning for near transfer. In learning something new, focus your attention just on the new material. Work to build just a few neural connections. Practice using these connections over and over again so that you can do the new thing very rapidly and accurately. Build a few very "strong," well-practiced neural connections.

Examples:

1. **Memorizing dates and events or people.**
   1492—Columbus, America
   1776—Revolutionary War

2.

3.

4.

5.

Chapter 7 Overhead Transparency 5
Learning for Far Transfer

Type 2 Learning—Learning for far transfer. In learning something new, focus your attention both on the new material and lots of different things that seem related. Work to build a large number of neural connections. Connect the new ideas to lots of different things you already know. Build a very large, "rich" set of neural connections.

Examples:

1. **Many people have cats as household pets. Household pets bring comfort and pleasure to their owners. There are may different kinds of household pets. Cats and dogs can live together as household pets. House cats are related to lions, tigers, and panthers; these are very large animals that live in the jungles of Africa and South America. There are very ancient paintings that show Egyptians having cats as pets. Some people think cats have nine lives. "Curiosity killed the cat." I cried when our cat ran away.**

2.

3.

Chapter 7 Overhead Transparency 6
What Teachers Can Do to Help Increase Far Transfer

1. Give essay tests.

2. Give open-book tests.

3.

4.

Chapter 7 Overhead Transparency 7
What Students Can Do to Help Increase Their Own Far Transfer

1. **When a teacher presents an idea I feel is important enough to memorize, I do a free association until I link up with something that is really important to me.**

2.

3.

4.

5.

Chapter 7 Overhead Transparency 8
Chapter 7 Summary

CHAPTER 7 SUMMARY

You can get better at far transfer by study and practice. When you are learning how to solve a new type of problem, think about the following questions:

1. **What are the underlying concepts or principles?**
2. **How are these concepts related to other things I already know? (Do metacognitive thinking that will increase far transfer.)**
3. **What are the procedures needed to solve the problem?**
4. **Can a computer or other machine help carry out these procedures?**

Chapter 8. Modeling
Overview

Rationale and Overview

Chapter 7 focuses on transfer of learning. The idea is to increase your ability to build on your own previous learning. Quite a bit of the discussion builds on a model of the human brain in which information is stored in interconnected neurons and thinking is a neural activity. Learning involves building interconnections and strengthening interconnections. We encourage automaticity and near transfer by concentrating our learning on a relatively limited number of closely interconnected neurons. We encourage far transfer by concentrating on building widely varying interconnections among the ideas being studied and other ideas that have been previously learned. We can picture this as building and strengthening the neural links between pieces of information and ideas stored in different parts of the brain.

This type of picture, description, or representation of the human brain and learning processes is clearly a gross oversimplification. But it is a *model* that may help us in communicating with each other, in teaching and in learning. A model is not the same thing as the object being modeled. (The map is not the territory.) However, models are essential in problem solving.

Computers are a powerful aid to modeling. They bring a new dimension to this field, thereby making a major contribution to problem solving. One approach to understanding this is to develop an understanding of the overall idea of modeling and the roles that modeling play in problem solving. That is the approach used in this book.

To understand and think about a problem, one must have develop a mental model for the problem. Mental models are very useful because they can be easily manipulated in one's mind, because they easily can be changed, and because they form a basis for communication with other people.

Mental models can be "translated" or expressed via a combination spoken language and body language. That is, people can communicate with each other via verbal and nonverbal (body) language. We will call the results *verbal models* or *verbal/body-language models.* Verbal models are an important aid to problem solving because they help people to build on the previous work of others and they facilitate group projects.

Reading and writing are a tremendous aid to problem solving because they facilitate the transfer of verbal models over time and distance. The words of a verbal model can be written down, carried to other places, and placed in a library.

Notice that it is more difficult to do this for a verbal/body-language model. That is, verbal modeling is inherently more expressive than written modeling.

Reading and writing are also important because they are a major supplement to the storage, processing, and retrieval capabilities of the human brain. (We include drawings, paintings, and so forth as part of written models.) It is clear that written models are a useful aid to problem solving. A highway map of a state is not the same as the roads and cities in the state, but it is a useful aid to solving problems that have to do with driving between cities in the state.

Computer models combine certain characteristics of mental modeling, verbal modeling, and written symbolic modeling. Computers can be used to help build, store, manipulate, and make use of models as an aid to problem solving. Computers can be interconnected so that a number of people can simultaneously share a computer model and work to build a model to help solve a particular type of problem. This type of cooperative computer-mediated problem solving is, in itself, revolutionary. Our educational system needs to prepare students to work in this world.

Chapter 8 presents an overview of modeling and its role in problem solving. The chapter builds a case for the importance of computer modeling as a new type of aid to problem solving.

This chapter of the Teacher Lesson Plans contains two lesson plans. The first focuses on the general idea of modeling, moving from mental modeling to verbal modeling to written symbolic modeling to mathematical modeling. The second lesson focuses specifically on computer modeling. The two lessons together are designed to give students an increased understanding of how they can learn to build and make use of a wide variety of models in problem solving. The lessons provide some insight into the capabilities and limitations of different types of models as an aid to solving different types of problems. For example, a mental model or a verbal model may be far more useful than a computer model in dealing with an interpersonal problem.

Coordination With Computer Literacy Courses

One of the main purposes of a computer literacy course is to help students learn about how computers are affecting our world. Computer modeling has brought a unique new dimension to problem solving. The cooperative building and use of models to help solve problems is of growing importance and adds still another dimension to attacking difficult problems. Thus, modeling, and the roles of computers in modeling, is an important topic in a computer literacy course.

1. Computer applications.

   A. A map is not the territory. A financial spreadsheet for a business is merely a model—it is not the finances of the business. It is reasonable to argue that every model starts as a mental model. It then can be represented in other forms, such as in a verbal model, a written model, a mathematical model, or a computer model. You want your students to understand this idea and how this helps in problem solving.

Select any generic computer application software, such as a graphics package, word processor, or spreadsheet, that your students are learning to use. Help your students analyze how this tool is used to build a computer model. For example, a word processor is used to build a computer model consisting of words and pictures arranged in a sequential fashion. Then have them compare and contrast the value of the computer model versus other forms of models for the same information or task.

B. A hypertext or hypermedia system facilitates building a computer model of words, pictures, and sounds designed to be viewed in a nonsequential fashion. Compare and contrast a word processor with a hypermedia system as an aid to representing a mental model.

C. A spreadsheet can be viewed as an aid to building certain types of mathematical models. Think about the difficulties students have in learning to use a spreadsheet. Are the difficulties mainly syntactical—learning the symbols and what keys to press to put characters into cells? Or are the difficulties mainly model building and problem solving—figuring out how to build a spreadsheet model for a problem? In some sense, instruction focused at the key-press level stresses lower-order thinking skills. Instruction focused at the model-building and problem-solving level stresses higher-order thinking skills.

2. Computer programming.

A. A computer program is a model. It is a computer representation of data structures and control structures that represent key aspects of a problem being addressed. When you teach computer programming, do you use the vocabulary and ideas of model building? Discuss these ideas with your students.

B. A programming language contains a great deal of vocabulary and special symbols or notation. Instruction in the language can focus on learning the vocabulary, notation, and primitives. In some sense, this is a focus on lower-order skills. Alternatively, the focus can be on using the language to build computer models as an aid to problem solving. Examine the computer programming course you teach. How much does it emphasize modeling and other related higher-order thinking skills? What might you do to increase the emphasis on this? Note that such higher-order skills readily transfer to learning other programming languages.

C. Why do we have so many different programming languages? One answer is that each language is specifically designed to help build certain types of models. COBOL was designed to help build business models, while FORTRAN was designed to help build the types of math models useful in science and engineering. Compare and contrast several different programming languages from this model-building point of view. What are the strengths and weaknesses of the language(s) you are teaching to your students? Are your students learning these strengths and weaknesses?

3. Computer awareness, including exploration of social and vocational issues.

A. What are the similarities and differences between a mental model and a verbal/nonverbal model? What is gained and what is lost as one attempts to translate one into the other? Do you think we will ever have a computer system that can do a good job of translating between natural languages? Discuss this from your understanding of how verbal/nonverbal models are representations of mental models but are clearly not the same as mental models.

B. One idea underlying hypertext is that all readers might comment on and contribute to a text they are reading. A hypertext document would thus become a living, growing, changing document that is reflective both of the original author and the readers. Compare and contrast this with the static nature of printed materials. Discuss the merits of having hypertext books in a library. What are the social, cultural, or historical implications of having books that their readers change over time?

Lesson Plan 16. Noncomputer Models

Primary Goals

1. Students will learn that they routinely make use of mental, verbal, and written models as an aid to problem solving and that model building is essential in problem solving.

2. Students will learn that skills in building and using models can transfer to a wide variety of problem-solving areas.

Prerequisites

1. (General) It is assumed that all students have a reasonable level of skill in translating their mental models into verbal/nonverbal models and also into written symbolic models. All students have had experience in building and using math models, although they may have had little or no formal instruction on such model building.

2. (Specific) Students have read Chapter 7 and have thought about their transfer-of-learning habits. They are consciously aware of the importance of transfer of learning and of learning in a manner that increases transfer. They are beginning to think about transfer of learning as they study and as they encounter new ideas.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson is designed to fit into one class period. Allow students about 15 minutes to read Chapter 8: Modeling and to do some of the activities they encounter during this reading. The Teacher Lesson Plans contain two lessons based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 8 contains seven new terms:

computer symbolic model (computer model)
mathematical model
mental model
model; modeling
scale model
written symbolic model (written model)
verbal model

Objectives

1. Students will recognize that when they are talking they are forming a verbal model.

2. Students will recognize that when they are writing, they are forming a written symbolic model.

3. Students will identify a variety of models used to represent the ideas in a class and/or used to solve the types of problems that occur in that class.

Description

Background

There are many different ways to represent, or model, a problem. Examples include mental models, verbal/nonverbal models, written symbolic models, scale models, mathematical models, and computer models. Each has certain advantages and disadvantages as an aid to problem solving.

The human mind naturally and automatically builds models and makes use of these models. The development of reading and writing provides a powerful aid to the mind in model building and in processing information contained in a model. It is clear that reading and writing, as aids to problem solving, have changed the societies of the world.

Computers are a powerful new aid to building and using models. Moreover, in conjunction with telecommunication access to the computer models, computer modeling gives a unique new way for people to work together to solve certain types of problems. Through telecommunications, people located in many different places can examine and work to build the same model as they work together to solve a problem.

Teaching Procedures

1. Begin by asking your students to build a picture in their heads—a mental description—of a close friend. The mental picture should include memories of pleasant times spent together and the good feelings of having this person as a friend. Point out to your students that they have just formed a mental model of their friend.

2. Now have your students write a description of their friend in their journals. The written description should be a representation of their mental model. In debriefing students about this activity, point out that it can be very difficult to translate a mental model into a written model. A poet may be especially good at this. Did any of your students draw a picture of their friend? How does this relate to the idea, "A picture is worth a thousand words"?

3. Now display Chapter 8 Overhead Transparency 1: Organize Your Thinking. Explain that each student formed a mental model of a friend. The mental model is clearly not the same as the friend. (A map is not the territory.) However, the mental model is a representation of the friend and the friendship.

4. Display Chapter 8 Overhead Transparency 2: Types of Models. Use this to facilitate a whole-class brainstorming approach to building a list of the types of models people use to help solve problems. For each type of model suggested by a student, have the student give an example of a type of problem it can help solve.

   You may want to do this activity in small discussion groups. Provide each small discussion group with a piece of butcher paper and have each group write examples of models and their uses. Encourage group discussion on the wide range of uses of a particular type of model. Post the group results in the front of the room and use them as a basis for class discussion.

   Debrief the students by pointing out that there are many different types of models. Make sure the developed list includes mental, verbal, written, and scale modeling. Emphasize that a particular type of model can be used to help solve a wide range of problems and relate this to transfer of learning. If one learns to build and use a particular type of model, one can transfer this knowledge and skill to a wide range of problem-solving situations.

5. Give students about 15 minutes to read Chapter 8: Modeling, making sure that all the students get through the journal-writing activity EXAMPLES OF USING DIFFERENT KINDS OF MODELS.

6. Do the Dream House modeling (Activity 5) given in the Additional Activities for Chapter 8. Students are to think about an ideal house they would like to own and live in. They are to form a vivid mental model. Then they are to

make a list of all of the types of models that might be useful in designing and constructing this house. Have all students work on this individually, writing lists in their journals. Then debrief by building a whole-class list. Display Chapter 8 Overhead Transparency 3: Models Used in Building a Dream House. The goal is to compile a very large list of different types of models that are used in thinking about, designing, and building a house.

7. After the list is completed, go through it carefully from the point of view of what problem each model is designed to help solve. You want your students to automatically associate model building with problem solving. You want them to understand that one overall problem (building a house) may make effective use of a very large number of different models.

8. Finally, begin to raise the question of how the models are interrelated. For example, suppose the amount of money you have available decreases. This could occur, for example, if interest rates go up and you can't afford to make larger payments. This means that you need to cut back on certain features of the house, landscaping, and so on.

9. This leads naturally to the idea of which aspects of all of the different models might be computerized and how the computerization might interrelate the different models. This example illustrates the real power of computer modeling in the building industry and why computers have become indispensable to architects and builders.

10. If time permits, have students finish reading the chapter and do activities 1 and 2 at the end of the chapter.

11. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to select one class (for example, next period's class). During that class they are to pay careful attention to the types of models used to represent the ideas and to solve the problems that occur in that class. They are to make a written list of the types of models used and how they are used. This list is to be turned in as a written assignment.

Student Learning Indicators

1. Formative evaluation (for the teacher).

    - Students were actively engaged and had fun.

- An atmosphere of discovery-based learning was created and maintained.

- You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.

- You were satisfied with how well the class went.

- Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

    - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.

    - All students wrote in their journals.

Extensions and Follow-up

Each academic discipline has its own special vocabulary and notation. Each makes use of certain types of models to represent results and to help solve problems. However, few teachers talk about modeling and few courses specifically teach the ideas of modeling. Have your students inquire into this. Have them explore with their teachers the types of models that are most appropriate to use within their teachers' disciplines.

Notes

Modeling lies at the very heart of problem solving. To solve a problem one must understand the problem. This means that one must be able to represent the problem (form a model of the problem). Thus, each academic discipline can be examined from the point of view of the types of models it uses and how it teaches students to use and create models.

However, most teachers do not think of their subject areas in terms of modeling as an aid to representing ideas and as an aid to problem solving. You may want to explore this with your fellow teachers. Your goal is to better understand what "modeling" means to them within their professional disciplines.

Lesson Plan 17. Building and Using Computer Models

Primary Goal

1. Students will understand that there are many different kinds of computer models.

2. Students will understand that computer models are very useful in solving a wide range of problems.

Prerequisites

1. (General) It is assumed that students have read the first eight chapters of the textbook.

2. (Specific) Students can give specific examples of where they have made use of mental, verbal, and written models to help solve a particular problem.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson is designed to be done in one class period.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 8 contains seven new terms:

computer symbolic model (computer model)
mathematical model
mental model
model; modeling

scale model
written symbolic model (written model)
verbal model

Objectives

1. Students will give examples of mathematical models and will point out how the same model can be applied to a number of different problems.

2. Students will give examples of models that can be represented on a computer.

3. Students will identify mental models that cannot be adequately and appropriately represented on a computer.

Description

Background

Today's computer-based hypermedia combines text, graphics, and sound with the storage, manipulation, and retrieval powers of a computer. In conjunction with telecommunication systems, this gives us a powerful new aid to developing models that can help solve a wide range of problems.

If students are to learn to make effective use of computer models, they need to understand how to build and use a full range of models (both on and off a computer) as an aid to problem solving. This means that each course students take needs to help them learn about the types of models appropriate to that course.

Computer models are particularly useful because they can be changed easily; because accumulated knowledge, one's own and that of others, can be incorporated easily into a model; and because the model can take advantage of the storage and computational powers of a computer.

Teaching Procedures

1. Begin by making sure all students have their books and a journal. Ask students to share examples of models and modeling that they have witnessed in various classes they are taking.

2. Display Chapter 8 Overhead Transparency 4: Math Models. Part of the "beauty" of mathematics lies in its concise notation and in the fact that one mathematical model can be used for a wide range of different problems. Thus, A = LW applies equally well to finding the area of a table top and the area of a farmer's field.

   Talk about the sequence of examples in the overhead. Place considerable emphasis on what is gained and what is lost as one develops and uses the concise notation of mathematics. A sterile formula A = LW in no sense represents the beauty of a nicely finished table top or the farmer's pride in growing a new pasture. Also, it takes a lot of schooling to learn to use mathematical models.

3. This is also a good place to review the idea of concept versus process. Area and perimeter are concepts that apply to a wide range of two-dimensional objects. For some of these objects there are simple formulas that can be used to help carry out a process for computing area or perimeter. (If you have studied math up through calculus, you realize that for most figures there are no simple formulas and no simple procedures for computing area and perimeter. However, computer programs have been written that can carry out the necessary computations for a wide range of figures.)

4. Here, we are assuming that all your students are familiar with the use of a word processor. If not, you can adapt this part of the lesson to some other piece of application software familiar to your students. Display Chapter 8 Overhead Transparency 5: Word Processor Models. Notice how the overhead combines text and graphics. You might point out that clip art is now readily available for use on a computer.

5. Now display Chapter 8 Overhead Transparency 6: Word Processor Models. Point out some of the changes that have been made to the previous overhead. A computer is a tremendous aid to making changes in a written symbolic model.

6. Display Chapter 8 Overhead Transparency 7: A Spelling Checker. The overhead illustrates the spelling checker that comes with *Microsoft Word 4.0*. It finds the misspelling of the word "storie" and makes a list of suggestions. None of the suggestions match the word "story" that the writer had in mind.

   Use the exercise to get students thinking about and talking about what computers can do for a person in helping to build models and about the limitations of computers. The major point to make is that computers are a very versatile tool but that we have lots of other tools that have proven effective over the years.

7. Display Chapter 8 Overhead Transparency 8: Modeling Situations Where Computers Are Not Very Useful. This activity can be done in small groups or in a whole-class discussion. The goal is to identify problem-solving situations in which one builds models but where computer models are not particularly useful or appropriate. For example, how do you use a computer to model a human emotion as an aid to communicate that you are angry at your friend?

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and activities. You may want to use Chapter 8 Overhead Transparency 9: Chapter 8 Summary.

Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to do activities 6, 7, 8, and 9 at the end of Chapter 8 as a written assignment to be turned in.

Student Learning Indicators

1. Formative evaluation (for the teacher).
    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
    - All students were engaged; at least half of them spoke at least once.
    - All students made written notes on possible answers to the discussion questions raised in class.
    - All students spent time in class and outside of class working on the assignment.

Extensions and Follow-up

In what sense is a word a model for something? In what sense is a metaphor a model? Such questions lead to the conclusion that models are everywhere and that we cannot function without using models.

It is clear that different representations (different models) for a particular thing will emphasize different attributes. Sometimes such differences are subtle. There is a difference between a "print" (even if it is a signed and numbered print) contrasted with an original painting. There is a difference between hand-lettered calligraphy and computer-produced lettering that "looks" the same.

You want to have your students become more aware of the subtleties inherent to different representations of the same thing. You want them to think carefully and consciously of the representational systems they are using (the types of models they build) and the advantages and disadvantages of each.

Notes

It is clear that a written symbolic model and a verbal/nonverbal model for ideas in your head will likely differ considerably. The development of written language has contributed greatly to the societies of the world. However, this has led to a decrease in oral tradition and, thus, to a loss. As we bring computers into routine use, we are making a significant change in our society. Through this change we may gain efficiency in solving a wide range of problems. At the same time there is a loss.

Educators who are strong advocates of using computers tend to deride other educators who resist "computerizing everything." It is important to understand the deep-seated and very important ideas that underlie such resistance to computerization of the world. Find a person you respect deeply but who has successfully resisted computerization. Talk about these issues.

Additional Activities for Chapter 8

1. It is not easy to describe someone or something so that another person will understand who or what you are talking about. This is an activity that can be done in pairs or in the whole class. As a whole-class activity, consider the following example. The teacher says:

   I am thinking about a teacher in this school. Write down the name as soon as you know it. Then raise your hand.

   A. The teacher is a man.

   B. The teacher is kind of short.

   C. The teacher has a big smile most of the time.

   D. Etc.

   As another example, consider the teacher saying again:

   I am thinking of an object in this room. Write down the name of the object as soon as you know it. Then raise your hand.

   A. The object is bigger than a loaf of bread.

   B. The object is located above the level of my desk.

   C. Etc.

2. This is an in-class activity to be done in groups of three. (This activity was given previously in the chapter as a small-group activity, but it can be expanded to a whole-class activity. It can be expanded to a competition between teams.) It is closely related to a variety of television game shows.

   Get together with two other students in the class. One person is to be the "sender" and the other two are to be the "receivers." The sender thinks of (forms a mental model of) a person, place, or thing. The sender begins then to describe the object (give a verbal model of it) but doesn't name it. The goal is to give a verbal model that is so good that the receivers can easily identify the object. The game ends when each receiver is sure that he or she knows what the object is.

   The same activity can be used with the sender using symbolic modeling, in this case, drawing a picture.

3. In this chapter we have discussed the strategy of using different models for a problem. Suppose you are trying to solve a problem using just a mental model. If that doesn't work, what other type of model should you use?

   You should try a different model. Should you try a verbal model, a paper-and-pencil symbolic model, or a computer symbolic model? It may be a lot of work to try just one of these. Which is apt to be the best one to try?

   This ties us back to Chapter 5. It is easy to memorize a lot of strategies. It is much harder to know when to use them. We know a person can get better at making such decisions by study and practice. Metacognition when practicing solving problems is very important. As you work to solve a problem, ask yourself questions such as:

   A. What strategy am I using right now?

   B. Why am I using this strategy?

   C. How well is it working?

   D. Do I know any other strategies I might use at this point in working to solve the problem?

   The point is, you are in school. You are learning to learn. You are learning to solve problems. The goal is to learn—to get better at solving problems. Seldom is the goal just to solve the problem. Almost always the emphasis should be on what you are learning by trying to solve the problem rather than on just solving the problem.

4. Brainstorm a list of problems that cannot be easily and usefully modeled in a computer. How are all of these problems alike?

   This would be a good activity for a class discussion. Can emotions be easily and usefully modeled in a computer? How about beauty? What do we mean by "easily and usefully" modeled in a computer? The goal is to take advantage of a computer's storage and processing capabilities. Situations in which good use is made of both the storage and the processing capabilities tend to be good examples of where a computer is a good aid to problem solving.

5. Dream House–Models of a House: This material could be used for a class discussion. It provides a good summary of many ideas in the chapter.

You already know you can have different models for a problem. For example, you can have a mental model, a written model, and a scale model. Each type of model helps you think about some aspect of the problem. In this section we give an example in which a large number of different models are used.

Suppose that a person is thinking about building a house. Here are a number of ways the proposed house might be represented.

A. A mental model. The mental picture might include details of the rooms, the outside structure, the landscaping, and the furnishings. It might include mental pictures of happy children growing up in this house. It might include pride of ownership.

B. A architect's blueprint drawings (plans) of the house. These contain the detailed information the builder needs. Some specific models that might be drawn separately include:

   1. A wiring diagram. The electrician needs this.

   2. A plumbing diagram. The plumber needs this.

   3. Exterior views. These drawings or pictures show how the house will look from different directions.

C. Scale drawings of the floor for each room. These show the details of how furniture will be placed. They may include samples of fabric to be used in drapes and color swatches of paint.

D. A financial analysis. This shows the cost of the house, the amount of the down payment, the amount of the loan, monthly payments, and so on. This helps the banker solve the problem of arranging a loan. It helps the owner figure out a budget.

E. A list of building materials. This is needed by the people who will buy the materials.

F. A time schedule for the builder. This is needed for scheduling the arrival of building materials and work to be done by specific groups, such as plumbers and electricians.

G. A structural analysis. This type of mathematical analysis gives information about how well the house will stand up to heavy winds, snow, earthquakes, and so on.

H. A landscaping plan. The landscaper needs this. It might also include a diagram of a sprinkling system.

As you can see, there are many different ways to model or represent a house. Each different model serves a different purpose. Each helps to solve some aspect of the problem of building a house.

Now look back over the long list of models for a house. A computer can be very helpful in creating all of these except the mental model. This is now becoming common. There are two advantages in using a computer. First, it is easy to make changes. Second, the computer can help do some of the work needed to solve a problem. For example, consider the problem of whether the house will be strong enough. This is a type of problem that structural engineers know how to solve. Computer programs have been written to solve this kind of problem.

Chapter 8 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

A model, such as a scale model, can serve in place of the "real thing" to help you solve problems. There are different ways to model (represent) a problem. One way is in your head—a mental model. A second way is by talking—a verbal model. A third way is by using writing and pictures. Still another approach is to model a problem inside a computer.

You can get better at problem solving by:

- **Learning a number of different ways to model a problem.**
- **Practicing the use of different models. Learning when one is better than another for you.**
- **Learning to develop and use computer models of problems.**

Chapter 8 Overhead Transparency 2
Types of Models

1. **A scale model, such as a model of an airplane. Can be used in a wind tunnel to help design a new airplane.**

2. **A wind tunnel. Can be used in place of a real wind in testing the design of an airplane.**

3.

4.

5.

6.

Chapter 8 Overhead Transparency 3
Models Used in Building a Dream House

1. Blueprints.

2. Payment schedule for loan.

3.

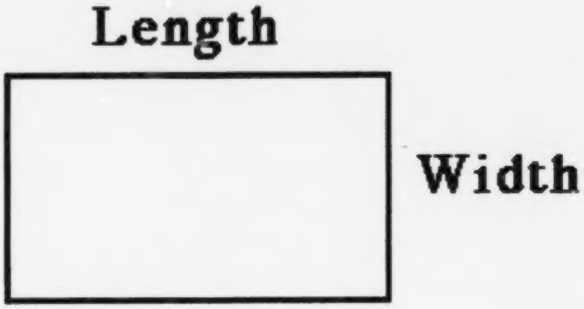
4.

5.

6.

7.

Chapter 8 Overhead Transparency 4
Math Models



The area of the table top is the length times the width.

The perimeter of the table top is twice the length plus twice the width.

The area of the field is the length times the width.

The amount of fencing needed to enclose the field is twice the length plus twice the width.

Area = Length x Width

Perimeter = 2 x Length + 2 x Width

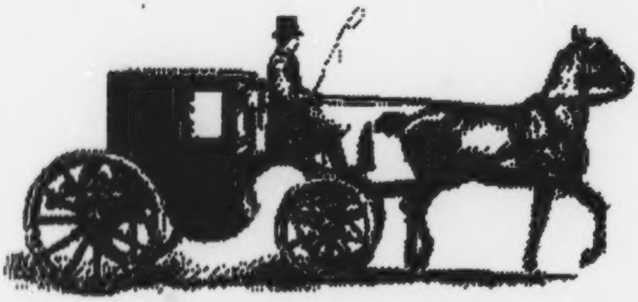
A = LW

P = 2L + 2W

Chapter 8 Overhead Transparency 5
Word Processor Models

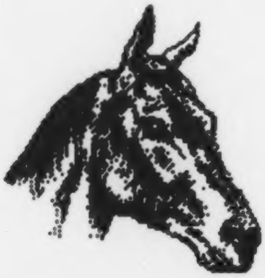
This is a story about a horse named Pat. Pat was a beautiful horse with very pretty eyes.

Pat was raised to be a farmer's work horse but instead ended up in the movies. Let me tell you how this happened.

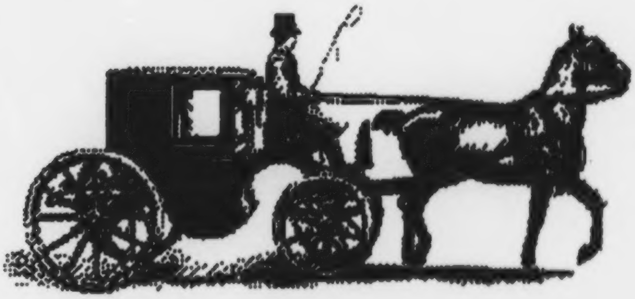


Chapter 8 Overhead Transparency 6
Word Processor Models

This is a story about a horse named Sam. Sam was a beautiful horse with very big, pretty brown eyes.



Sam was raised to be a farmer's work horse but instead ended up in the movies. Actually, these were ads for television. Let me tell you how this happened.

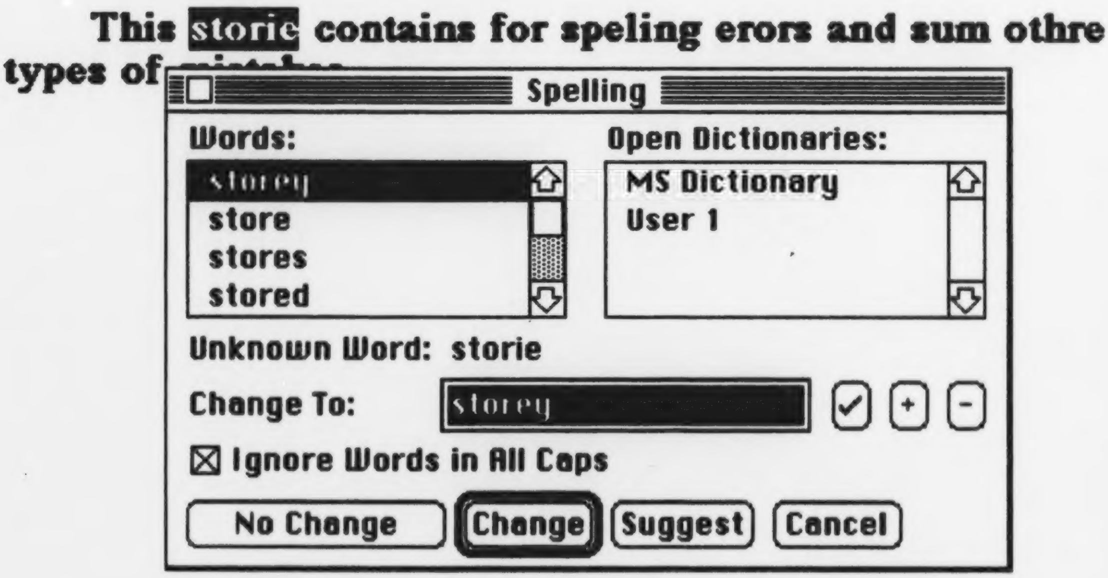


Sam

Chapter 8 Overhead Transparency 7
A Spelling Checker

This storie contains for speling erors and sum othre types of mistakes.

Can you find all of the errors? Will a spelling checker find all of the spelling errors? Is there computer software that will find the other errors?



This storie contains for speling erors and sum othre types of

Words:
storey
store
stores
stored

Open Dictionaries:
MS Dictionary
User 1

Unknown Word: storie

Change To: storey

☒ Ignore Words in All Caps

Chapter 8 Overhead 8
Modeling Situations Where Computers Are Not Very Useful

1. I'm mad at something my best friend did!

2.

3.

4.

5.

6.

Chapter 8 Overhead Transparency 9
Chapter 8 Summary

CHAPTER 8 SUMMARY

Modeling is a key part of problem solving. Mental modeling is most important. However, different types of models are useful in working on different aspects of a problem. A complex problem may require you to use a variety of different models.

Many different kinds of models can be represented inside a computer. Computer modeling may take advantage of a computer's:

1. **Storage capability.**
2. **Processing capability.**

A well-designed computer model is easy to change. This helps in working on hard problems.

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Chapter 9. General Purpose Computer Tools
Overview

Rationale and Overview

Chapter 8 focuses on modeling. You can think in terms of modeling using generic (general purpose) application tools, such as a word processor, spreadsheet, graphics package, database, or telecommunications network. You can think in terms of modeling using more specialized applications, such as a CAD/CAM (computer-assisted design/computer-assisted manufacturing) system, desktop publishing, or a computerized music composition and synthesis system. Finally, you can think in terms of special purpose and general purpose computer programming languages as an aid to building models. Chapter 9 focuses on generic application tools but lays groundwork for the study of more specialized application tools. Chapter 10 discusses computer systems and computer programming as aids to modeling.

As mentioned earlier in the Teacher Lesson Plans, there are three common approaches to computer literacy. One is based on the study of social and vocational issues—how computers are changing our world. A second is based on learning to use computer applications and integrating their use into a variety of subject matter areas. The third is based on studying computer science and computer programming. (Art Luehrmann, who coined the phrase "computer literacy" in the early 1970s, placed the greatest emphasis on this third approach.) Many people argue that a computer-literate person has balanced knowledge among these three components of computer literacy. The nature of the balance—what receives the most emphasis—should depend on the particular interests of the person and the types of fields being studied.

The first eight chapters of *Problem-Solving Models for Computer Literacy* can be integrated into almost any type of computer literacy course, or they can serve as a basis for a self-contained course on problem solving. The ninth chapter focuses on general purpose computer application tools. This material may prove redundant and duplicative of earlier efforts in many computer literacy courses. If a computer literacy course focuses mainly on application tools, then essentially all of the ideas of Chapter 9 should have been covered long before students reach this chapter. In that case, you may want to use these materials strictly as a summary, overview, and review that covers application software in a unifying manner.

General and special purpose computer application tools will eventually lead to major changes in the content of our precollege curriculum. It is possible for students to become proficient in the use of a variety of generic computer application tools by the time they finish elementary school. We have lots of evidence that such students can become proficient in using a word processor, database, graphics package, or telecommunications network.

Thus, we can begin to imagine an educational system in which all students become proficient in the use of these computer tools before they begin junior high or middle school. Junior high school and middle school teachers who are subject matter specialists and who teach in their specialty areas could begin to assume that all students were familiar with the generic software tools. A writing teacher could expect that all papers would be word processed. A social studies teacher could assume that all students know how to retrieve information from computerized databases and know how to create such databases.

This provides a foundation for a still larger change. In the worlds of business, industry, and research, we are seeing the development of highly specialized computer tools designed to increase the productivity of workers. To use these tools effectively, one needs to have a great deal of knowledge about the types of problems being addressed. To effectively use a math tool such as Mathematica, you need to know a great deal of mathematics. The tools and the subject matter are becoming woven together.

This suggests that our schools will eventually operate under the same conditions. As students begin to study specific subjects in secondary school, they will study subjects in which very powerful computer tools exist. The study of the computer tools will be woven into the very fabric of the subject matter, and students will not readily distinguish where the subject leaves off and the computer begins.

Chapters 9 and 10 of *Problem-Solving Models for Computer Literacy* focus on generic application tools and on computer programming. These two short chapters are not intended to teach the use of a range of generic application packages or to teach computer programming. Rather, they are intended to help summarize key ideas that underlie such computer software.

Coordination With Computer Literacy Courses

Computer literacy is a balanced and functional knowledge of a number of different components. Computer applications are one of these components. Nowadays it is hard to believe that a person would think of himself or herself as being computer literate and not be reasonably familiar with several of the generic computer application packages.

Chapter 9 of *Problem-Solving Models for Computer Literacy* contains a summary of key ideas underlying general purpose computer application packages. Here are some ideas on how to integrate this material into different types of computer literacy courses.

1. Computer applications.

   A. The basics of education include reading, writing, arithmetic, speaking, and listening. Five of the most widely used computer application packages are the word processor, database, spreadsheet, graphics, and telecommunications/networking. Compare and contrast the basics of education with these application packages.

   B. There are two common approaches to making general purpose application packages available. One approach is an integrated package, such as *AppleWorks* or *Microsoft Works*. A second approach is via individual, self-contained pieces of software. What are the advantages and disadvantages of each approach? Which is more appropriate to the needs of students and our educational system?

   C. Many educators think that a word processor is the single most important computer application. This orientation has led to considerable emphasis on teaching keyboarding in many elementary schools. Contrast this idea with the suggestion that databases and computerized information retrieval are the most important computer applications in education. What changes would occur in education if all students were proficient in the use of a word processor and had good access to computers for this purpose? What changes would occur in education if all students had good access to computerized information retrieval systems and were proficient in the use of databases as an aid to problem solving? Explore these ideas with your students.

2. Computer programming.

   A. Every programming language contains some sort of editor that allows one to type in text and to edit text. Compare and contrast such an editor with a word processor. (This discussion may be particularly interesting if your students have been using *LogoWriter*.)

   B. A computer programming language contains data structures and control structures. That is, the language contains provisions for representing and storing one or more types of data and organized forms of this data (perhaps in an array or a list). The language contains provisions for carrying out repeated actions on the data (loops, recursion). Select a general purpose computer application package. Examine it from the point of view of data structures and control structures. In what ways is the application package like a programming language? In what ways is it different?

   C. Pick an application package, such as a word processor, database, or spreadsheet. Using a programming language that you have been studying, write a computer program that has a number of features of the computer application package. As you work on this task, think about the capabilities and limitations of the programming language for accomplishing such a programming task.

3. Computer awareness, including exploration of social and vocational issues.

   A. Many students are learning touch keyboarding in elementary school, and many have very easy access to word-processor facilities both at home and at school. However, the great majority of students lack both of these "advantages." Is this fair?

   B. Should students be allowed to make use of calculators and computers while taking tests? If a student has been given a lot of instruction on how to use a computer system to solve a particular type of problem (for example, using a word processor to write), is it fair to make the student take tests not using the computer system?

   C. Conduct a survey of how many of your students have easy access to a computer at home. How many make use of the home computer to do school work? Use this type of data as a basis for discussion of computer equity issues.

Lesson Plan 18. General Purpose Computer Tools

Primary Goals

1. Students will learn that a word processor, database, graphics package, spreadsheet, and telecommunications/networking package are all examples of general purpose computer tools.

2. Students will learn that all general purpose computer tools have a number of common characteristics, such as wide usefulness and user friendliness.

Prerequisites

1. (General) It is assumed that all students have had some experience using one or more general purpose computer application tools, such as a word processor or a database.

2. (Specific) Students have an introductory level of understanding of computer modeling. They have read Chapter 8 of *Problem-Solving Models for Computer Literacy.*

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy.*

Time Considerations

This lesson is designed to fit into one class period. However, it can easily be expanded to several class periods. The Teacher Lesson Plans contain only one lesson based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 9 contains nine new terms. This is quite a bit of new vocabulary to introduce in a single chapter. Make sure you use these terms frequently during the class time devoted to this chapter.

computer network (network)
database
desktop publishing
electronic mail (E-mail)
graphics (computer graphics)
human-machine interface
hypertext
spreadsheet
user friendly

Objectives

1. Students will state several features common to most general purpose computer tools.

2. Students will compare and contrast two different versions of a computer tool (for example, two different word processors) on several criteria including their overall user friendliness.

3. Students will identify uses of general purpose computer tools that they could be making in the courses they are taking if they had easy access to computers and encouragement from their teachers.

Description

Background

Computer tool application packages can be considered as productivity tools. Some of these productivity tools are useful over a wide range of problem areas. Examples include the word processor, database, graphics, networking/telecommunications, and spreadsheet. All but the last of these are readily learned by grade school students. A spreadsheet is an aid to a certain type of mathematical or business modeling. Because this is a rather sophisticated type of modeling, learning to make effective use of a spreadsheet tends to be more difficult than learning to use the other computer tools in the list.

Each of the general purpose computer tools is available as a self-contained software package. However, it is frequently helpful to use several or perhaps all of these tools in dealing with a single problem. Thus, software developers have worked on providing easy communication among these tools. Sometimes this is done by integrating two or more of the tools into a single software package. *AppleWorks*, *DeskMate*, and *Microsoft Works* are examples of integrated packages widely used in education. Integrated packages usually have a consistent human-machine interface. That is, learning to use one tool in the package helps one learn to use a different tool in the package.

Teaching Procedures

1. Begin by displaying Chapter 9 Overhead Transparency 1: Organize Your Thinking. Use this to briefly review some of the most common general purpose computer tools. Help your students to become more aware that there are lots of these tools and that many of them are useful to students.

2. Display Chapter 9 Overhead Transparency 2: User Friendliness. Use this to lead a whole-class brainstorming session to produce a list of features that make a piece of software "user friendly."

   You may want to do this activity in small discussion groups. Provide each small discussion group with a piece of butcher paper and have each group write examples of features that make a piece of software more user friendly. Post the group results in the front of the room and use them as a basis for class discussion.

3. Debrief students on this activity by pointing out that the design of user-friendly software applications makes a significant contribution to education. Generally speaking, user-friendly software is easy to learn how to use because its use seems "natural" relative to what the user already knows. The software is tolerant of user errors so that a trial-and-error approach to learning will be successful while actually using the software to solve problems.

   Have your students think about such trial-and-error approaches to learning. Are there some subjects where this approach is more appropriate than others? Do some teachers make more use of this approach than other teachers do?

4. Display Chapter 9 Overhead Transparencies 3 and 4: Features of Good Software Tools. Select a piece of application software that all of the students know. For each of the four features listed on the overheads, have students vote on their perceptions of an appropriate rating. When major differences of opinion emerge, lead the class in a discussion of these differences of opinion. In some sense, the quality of a piece of software depends on the user.

5. Give your students about 15 minutes to read Chapter 9. If you want to extend Chapter 9 to several lessons, you can spend considerable time discussing the general features and usefulness of each of the major application tools mentioned in the chapter.

6. Assign as seatwork the evaluation of one or more pieces of application software that students have used. The evaluation can be done using the five-point scale on the four features F1-F4. It can also be done using the general

criteria of how each piece of software is used as an aid to modeling and problem solving. For example, a word processor is useful for:

A. Organizing your thoughts.
B. Revising.
C. Improving mechanics.
D. Publishing.
E. Making use of your previous writings.

Thus, you can rate a word processor on each of these criteria.

The software evaluation can be done individually and then compared in small groups. Alternatively, it can be done in small groups from the very beginning. The goal is to get your students to become critical observers of good and bad features in the software they use.

7. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. You may want to use Chapter 9 Overhead Transparency 5: Chapter 9 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Students are to select a general purpose application package that they have not used before. They are to begin to learn to use it. As they learn, they are to keep detailed notes in their journals about their perceptions of user friendliness for a beginner. A summary is to be written up to hand in.

Student Learning Indicators

1. Formative evaluation (for the teacher).

   - Students were actively engaged and had fun.
   - An atmosphere of discovery-based learning was created and maintained.
   - You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.
   - You were satisfied with how well the class went.
   - Your learned some new things about your students and/or yourself.

2. Assessment of student performance.

   - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.
   - All students wrote in their journals.

Extensions and Follow-up

In this lesson we emphasized general purpose application tools that are useful across many disciplines. Each discipline is developing special purpose software that is particularly valuable in solving the specific problems of that discipline. Have students study these in contrast to general purpose software. For example, how does a sophisticated desktop-publishing program compare to a word processor?

Notes

It is difficult to design application software that is easy both for a beginner to learn and use, and that meets the needs of a more experienced user. It is difficult to develop software that is useful over a wide range of disciplines and that has the depth of coverage needed by a professional in a specific discipline. As computers get more powerful, more features can be incorporated into application software.

For these and other reasons, we can expect application software to continue to get better and better. However, already the user's manuals for some pieces of application software are many hundreds of pages long. Entire college and business college courses are offered on a single piece of software. It can take many hundreds of hours of study and practice to master a piece of application software. For some software, the level of effort required to learn the application software is comparable to that required to learn a general purpose programming language. Indeed, some application software includes a built-in general purpose programming language.

Additional Activities for Chapter 9

1. Suppose you were going to invent a piece of general purpose application software that would be especially useful to students such as yourself, but it was to be different than software you have used before. What would its features be? What types of student-oriented problems would it help you to solve?

2. Do some writing using one word processor on a computer and then attempt to transfer the resulting document to another word processor on the same or on a different type of computer. What is easy and what is hard? What would make the overall process easier?

3. Compare and contrast the quality of a particular application in an integrated package with an application package specifically devoted to this particular application.

4. Teachers: It is interesting to experiment with giving students access to a computer for test taking. For example, the next time you give an essay test, why not offer students the option of using a word processor to take the test? If you have some experienced word-processor users in the class, encourage them to take you up on the challenge.

5. Teachers: How are you going to deal with term projects done in hypertext or in hypermedia? This can be further complicated by having teams of students working on such a project. Each may bring different resources to the project. For example, one student may supply the art work, a second the music, a third the writing, and a fourth the overall leadership needed to bring the project to completion. How do you assess the project and the students?

Chapter 9 Overhead Transparency 1
Organize Your Thinking

ORGANIZE YOUR THINKING

Some of the basics of education include reading, writing, and arithmetic. These are "tools" that help you understand and solve many different kinds of problems.

There are some computer tools that are useful in solving a wide range of problems. Examples of these general purpose tools include:

- **Word processor (modeling using writing).**
- **Database (storing and looking up information).**
- **Graphics (modeling using diagrams and pictures).**
- **Spreadsheet (math modeling).**
- **Networking (connecting computers with databases, people, and other computers).**

Chapter 9 Overhead Transparency 2
User Friendliness

1. Doesn't wipe me out when I make a little mistake.

2.

3.

4.

5.

6.

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Chapter 9 Overhead Transparency 3
Features of Good Software Tools

F1. The software is useful in helping to solve many different kinds of problems from many different fields. It may be useful in every subject you study in school.

1	2	3	4	5
Very Poor		Okay		Very Good

F2. The software is useful in working on the kinds of problems in which one needs to make many changes. The computer helps you to try different ideas and to see the results of your trials.

1	2	3	4	5
Very Poor		Okay		Very Good

Chapter 9 Overhead Transparency 4
Features of Good Software Tools

F3. The software takes advantage of the power of a computer to do quite a bit of work for you. Both the storage and the processing power of the computer are used.

1	**2**	**3**	**4**	**5**
Very Poor		**Okay**		**Very Good**

F4. The software is easy to learn how to use and easy to use. It is user friendly. You can easily learn how to use the software to help solve the kinds of problems you are studying in school.

1	**2**	**3**	**4**	**5**
Very Poor		**Okay**		**Very Good**

Summary Rating: Overall perceived quality as an aid to modeling and problem solving.

1	**2**	**3**	**4**	**5**
Very Poor		**Okay**		**Very Good**

Chapter 9 Overhead Transparency 5
Chapter 9 Summary

CHAPTER 9 SUMMARY

Some computer software is designed to help solve a wide range of problems. This software can be used to build computer models for a wide range of problems.

Key features of general purpose software include the following:

F1. The software is useful in helping to solve many different kinds of problems from many different fields.

F2. The software is useful in working on the kinds of problems in which one needs to make many changes.

F3. The software takes advantage of the storage and processing power of a computer to do quite a bit of work for you.

F4. The software is easy to learn how to use.

Chapter 10. Computer Systems Overview

Rationale and Overview

Chapter 9 focuses on general purpose application tools as an aid to modeling and solving problems. Gradually these application packages have become more and more powerful, and they have become much more user friendly. Gradually they have been built into integrated packages, or software has been provided so that individual packages can readily communicate with each other. Thus, their capabilities have grown steadily.

Meanwhile, we have seen a marked decline in the teaching of computer programming and computer science at the precollege level. It would appear that there is a causal relationship. It seems clear that many people want to know how to use a computer as an aid to problem solving and to increase their productivity. Historically, people were led to believe that this meant they needed to learn how to write computer programs. The advent of personal computers and good-quality application packages has certainly changed that. Now, most people have little need to know how to write computer programs to make effective use of a computer.

This last sentence bears repeating. A rapidly increasing number of people make routine use of computers on the job. Most have little need to be able to write computer programs for use on the job. This does not mean they would not benefit from having increased understanding of computer systems and some of the ideas of computer programming.

Chapter 10 focuses on computer systems and computer programming. The information provided is rather general. It can be integrated into any type of computer literacy course. If you are teaching a computer-programming-oriented computer literacy course, you most likely have already covered the main ideas from Chapter 10.

The issue of who needs to learn some computer programming and kind of programming needs to be taught will continue to be debated far into the future. In the early history of computer programming, a person needed at least a year of study and practice to become reasonably decent at programming in machine or assembly language. It took a particular type of mind and problem-solving ability to get really good at assembly language programming.

However, researchers and software developers gave a lot of thought to how to solve the problem of helping a wider range of people learn to write computer programs. The result was the development of higher-level programming languages. While there were a number of earlier attempts to develop such languages, FORTRAN, developed between 1954 and 1957, was the first really successful higher-level programming language. A scientist or engineer could gain a useful, functional knowledge of FORTRAN in a couple of weeks.

Initially, FORTRAN was taught mainly to scientists and engineers who had both a substantial background in mathematics and considerable skill in problem solving. They learned FORTRAN to help them solve problems in the field where they were already well-qualified professionals.

Gradually, however, the teaching of computer programming spread to college undergraduate courses and even into high schools. It soon became evident that students at all levels could learn the syntax and semantics of a higher-level programming language. This was helped by the development of BASIC during the mid-1960s. BASIC was specifically designed to be appropriate for college undergraduates, and its use quickly spread even into elementary school.

As the teaching of programming spread, two things became evident:

1. Almost anyone could learn to write simple computer programs that would do some simple things.

2. Most people found that it was difficult to learn to write programs well enough to solve moderately difficult problems.

It is obvious why most people find programming difficult. First, most programming languages are highly mathematical in nature. A programmer must be able to do a mathematical-like, very precise type of problem analysis and thinking. Second, most students who are learning to write computer programs are writing programs in areas where they have little professional knowledge. They cannot draw on professional knowledge to provide feedback, to help in error detection and error correction, and to provide motivation or sense of purpose. Third, one writes computer programs to solve problems. Most students have relatively poor skills in problem solving and have had little formal training in problem solving.

The development of Logo in the late 1960s and its implementation on microcomputers in the late 1970s provided educators with a programming language that could be used even with primary school children. However, the three difficulties cited above remained. Young children lacked the mathematical background and precise thinking that is helpful in learning to program. They had no professional field of expertise in which they could apply their programming skills. Young children had not had formal instruction in problem solving. A fourth difficulty soon became evident. Most elementary school teachers were ill prepared to help young students learn a programming language such as Logo.

Historically, that brings us up to date. Many precollege students receive some introduction to computer programming. Many teacher training institutions require preservice teachers to have one- or two-week introductions to BASIC and/or Logo as part of a course, such as Fundamentals of Computers in Education. There are some very important intellectual ideas that have been developed in the field of computer and information science that could be taught to students. By and large, however, our educational system is doing a poor job of this.

Perhaps the single most important idea to come out of the field of computer and information science is that of an *effective procedure*. An effective procedure is a detailed, step-by-step set of instructions with the following characteristics:

1. The set of instructions is designed to accomplish a specified task (solve or help solve a specified type of problem).

2. The set of instructions can be mechanically interpreted and carried out by a computer (or a computerized machine, such as a robot).

The overall field of computer and information science studies a variety of aspects of effective procedures. Here are some examples:

1. Computer engineering—build computers that are faster, more cost effective, able to store larger sets of instructions and data sets, and so on.

2. Analysis of algorithms—determine how long it will take for a particular type of set of instructions to solve a particular type of problem. Develop faster algorithms. Determine what types of problems are inherently not solvable by computer.

3. Artificial intelligence—develop sets of instructions that are more intelligent-like, that are "smarter." Out of this has come a subfield known as expert systems, and with it has come the idea of knowledge engineering. Here, the goal is to develop effective procedures that can accomplish the same tasks as human experts within a problem-solving domain.

4. Human-machine interface—develop hardware and software systems that are more user friendly.

5. Graphics—develop computer hardware and software systems for effectively dealing with graphic representations of information.

6. Programming languages—develop programming languages better suited to developing effective procedures.

7. Software engineering—developing a science of writing computer programs to solve hard problems.

8. Information retrieval—develop effective procedures for the storage, manipulation, and retrieval of databases as an aid to problem solving.

9. Applications—develop computer applications that are user friendly and that are powerful aids to human productivity and problem solving.

10. Robotics—develop robots with appropriate sensors, visual systems, and manipulators that can be used in a wide range of applications.

11. Computers in education—understand computers as an aid to instruction, as an object to be studied, and as an aid to solving problems within every discipline. People are working on effective procedures to help teachers teach and to help students learn.

12. Computers in (name any field of research)—computers are affecting every area of human intellectual endeavor. Effective procedures are being developed specifically for problems in each field of research.

The list could be extended, but the current list should be sufficient to make the point that the field of computer and information science is a very large, intellectually rich, and growing field. It is impacting every area of research and human intellectual endeavor. It is one of the most important intellectual developments of humankind. It deserves to be a topic all students learn about as part of their general education.

At the precollege level, the main purpose of a computer programming and/or computer science course should be to introduce students to some of the key ideas in the field. Every student is capable of learning about the idea of an effective procedure. Every student is capable of experiencing some success in developing computer programs to solve problems. Every student is able to learn some of the difficulties in writing computer programs and in learning to be a good programmer.

Relatively few of your students will become professional computer programmers. A precollege student's introduction to computer programming should not be designed primarily to lay the groundwork to become a professional programmer. Instead, it should be an exposure to a very exciting, delightful field of study and of human accomplishment. Students should experience joy in discovering this field and in beginning to understand its capabilities and limitations. Students should come to understand how this field fits in with their own interests, capabilities, and limitations.

Chapter 10 of *Problem-Solving Models for Computer Literacy* gives only a brief introduction and overview of computer systems, computer science, and computer programming. This chapter is not intended to teach computer programming. Rather, it is intended to help summarize key ideas that underlie computer hardware and software systems and computer programming.

Coordination With Computer Literacy Courses

Computer literacy is a balanced and functional knowledge of a number of different components. Computer hardware and software systems and computer programming are two of these components. Nowadays it is hard to believe that a person would think of himself or herself as being computer literate without having some understanding of computer hardware and software systems and the idea of an effective procedure. Here are some ideas on how to integrate Chapter 10 material into different types of computer literacy courses.

1. Computer applications.

    A. Each application package can be viewed as an effective procedure designed to interact with a person to solve some particular type of problem. Explain the concept of effective procedure to your class. Then lead a discussion that analyzes various pieces of software familiar to your students from an effective-procedure point of view. For example, a word processor does not solve the problem of doing writing for a student. Rather, it aids in displaying one's writing in a form that makes it easy to read and easy to modify.

    B. In some sense, every general purpose application package can be viewed as a limited programming language. Each general purpose application package contains provisions for giving a computer a set of instructions. In some cases the computer carries out each instruction as soon as it is given. In other cases it is possible to give the computer a number of instructions that it then carries out. For example, many word processors allow the user to specify a variety of different printer options and then to specify that a document is to be printed.

    Select a general purpose computer application familiar to your students. Analyze it from the point of view that it is a very special purpose programming language. What types of data structures can it be used to create? What types of actions can one carry out on these data structures?

    C. Developing a spreadsheet model for a problem and writing a computer program for a problem have a lot in common. It is easy to develop a spreadsheet model that contains bugs, so that it needs to be tested and debugged. It is also easy to make an error when specifying a search strategy in a database. Discuss with your students how it might be possible to detect errors one makes in using a spreadsheet, database, or other application software. To what extent do your students receive careful instruction in detecting and correcting such errors?

2. Computer programming.

   A. Every programming language contains some sort of editor that allows one to type in text and to edit text. Compare and contrast such an editor with a word processor. (This discussion may be particularly interesting if your students have been using *LogoWriter* or some other programming language that incorporates a rather general purpose word processor.)

   B. A computer programming language contains data structures and control structures. That is, the language contains provisions for representing and storing one or more types of data and organized forms of this data (perhaps in an array or a list). The language contains provisions for carrying out repeated actions on the data (repetition, recursion). Select a general purpose computer application package. Examine it from the point of view of data structures and control structures. In what ways is the application package like a programming language? In what ways is it different?

   C. Pick an application package, such as a word processor, database, or spreadsheet. Using a programming language you have been studying, write a computer program that has a number of features of the computer application package. As you work on this task, think about the capabilities and limitations of the programming language for accomplishing such a programming task.

3. Computer awareness, including exploration of social and vocational issues.

   A. If a computer is to solve a problem, someone must develop an effective procedure that tells the computer how to solve the problem. It turns out that it is difficult to write an effective procedure directing a computerized robot to do tasks that a person can easily learn to do. Select a task such as going from one's desk to a pencil sharpener, sharpening a pencil, and returning to one's desk. Have students write effective procedures to sharpen a pencil. (These procedures are to be carried out by other students who are pretending to be robots.)

   B. Do a whole-class brainstorming activity on making a list of different types of problems for which no effective procedure currently exists. Use this list to promote class discussion on limitations of computers. Are there certain categories of problems that people routinely solve but which computers cannot currently solve and may never be able to solve?

   C. What types of jobs will people have in the future? If a computer can solve a particular type of problem (accomplish a particular type of task) in a cost-effective manner, will such a job be turned over to the computer?

What does this mean in terms of the types of jobs that will be available to people? What are the educational implications of such issues?

Lesson Plan 19. Computer Systems

Primary Goals

1. Students will learn a definition of *effective procedure*.

2. Students will learn that the computer field is continuing to change very rapidly because of progress in developing both better hardware and better software.

Prerequisites

1. (General) It is assumed that all students have had at least a little exposure to a programming language, such as BASIC, Logo, or Pascal.

2. (Specific) None.

Materials Setup

1. (For the teacher)
    - Overhead projector, blank acetate, acetate pens.
    - Overhead projector slides from black-line masters in the Teacher Lesson Plans.
    - (Optional) Butcher paper, felt markers, and masking tape for use by students. These can be used in small-group brainstorming and discussion sessions that lead to the creation of summaries posted in the front of the room to facilitate whole-class discussions.

2. (For students) It is expected that students will have a journal, writing implement, and the book *Problem-Solving Models for Computer Literacy*.

Time Considerations

This lesson is designed to fit into one class period. However, it can easily be expanded to a large number of class periods. The expanded time can be used to teach some computer programming and/or to compare two different programming languages students have previously been exposed to. The Teacher Lesson Plans contain only one lesson based on this chapter.

Glossary

One major goal of the overall course is to help students increase their working vocabulary. Each chapter of the Student Lessons contains some words, phrases, and concepts that are boldfaced in the text and defined in the Glossary. Chapter 10 contains 10 new terms. This is quite a bit of new vocabulary to introduce in a single chapter. Make sure you use these terms frequently during the class time devoted to this chapter.

bug

central processing unit (CPU)
chip
computer system
debug
hardware
higher-level programming language
integrated circuit
machine language
software

Objectives

1. Students will give examples of procedures that they carry out "almost without thinking" to solve problems of personal interest.

2. Students will indicate how they detect errors in the types of personal procedures they routinely use to help them solve problems.

3. Students will practice procedural thinking—developing personal procedures or effective procedures.

4. Students will give examples of types of problems they have personal procedures to solve but for which there are no effective procedures.

Description

Background

A computer is a machine designed for the input, storage, manipulation, and output of symbols. If a computer is going to solve a problem it is necessary to:

1. Represent the problem using a computer.

2. Develop or obtain an effective procedure that directs the computer to carry out the steps needed to solve the problem. (The combination of the representation and the effective procedure is a computer model for the problem.)

3. Have computer hardware of sufficient storage capacity and speed to carry out the needed processing in a timely manner.

All people develop personal procedures that they eventually use routinely with little or no conscious thought. It is much more difficult to develop effective procedures that a computer can use (with no thought whatsoever) to solve problems. Procedural thinking refers to thinking about problems in terms of developing personal procedures and effective procedures to solve the problems. Procedural thinking is an important intellectual idea.

Teaching Procedures

1. Begin by displaying Chapter 10 Overhead Transparency 1: Organize Your Thinking. Use this and Chapter 10 Overhead Transparency 2: Computer Hardware System, to briefly introduce (or review) vocabulary such as hardware, software, computer system, CPU, and computer memory.

2. Talk about change—how the hardware components of computer systems are getting better. Primary and secondary memory are getting larger and more cost effective. The CPU is getting faster. I/O units are getting more versatile. As a very rough estimate, the cost effectiveness of computer hardware has improved by a factor of a million since the first mass-produced computers began to be made in 1951.

   The idea of an improvement by a factor of a million in the cost effectiveness of a useful product is hard to imagine. You might have your students think about developing a car or a ball point pen that is a million times as cost effective as early, mass-produced versions of these objects.

3. Display Chapter 10 Overhead Transparency 3: Effective Procedure. The overhead contains three examples of effective procedures. Have class members suggest other effective procedures that might be good primitives—good building blocks—in writing programs to solve more complex problems.

4. Display Chapter 10 Overhead Transparency 4: Personal Procedure. Lead a whole-class brainstorming activity in identifying a long list of personal procedures.

   You may want to do this activity in small discussion groups. Provide each small discussion group with a piece of butcher paper and have each group write examples of personal procedures. Post the group results in the front of the room and use them as a basis for class discussion.

5. How do you detect when you have made an error with a personal procedure? For example, you might use the wrong personal procedure or you might make a mistake in carrying it out. Have your students do journal writing on this question.

6. Display Chapter 10 Overhead Transparency 5: Errors in Using Personal Procedures. Debrief students about this journal-writing activity. Focus on the idea that with personal procedures, one knows a lot about the problem being solved and can easily recognize when one's actions are not helping to solve the problem. Compare and contrast this with computers, especially with complex computer programs that are being used to solve complex problems.

7. Give your students about 15 minutes to read Chapter 10. If time permits, assign activities 1 and 2.

8. Provide closure. Near the end of the period, get students to think about some of the important ideas covered in that day's discussions and readings. You may want to use Chapter 10 Overhead Transparency 6: Chapter 10 Summary. Each student is to decide on one idea he or she felt was particularly important. As time permits, these ideas can be shared by the whole class, in small groups, written down, or thought about at a personal level.

Student Activities

Give students an assignment of writing a brief essay that gives arguments for and against requiring all students to learn to write computer programs. The essay should summarize arguments for and against this requirement and then give the student's own, personal opinion on the subject.

Student Learning Indicators

1. Formative evaluation (for the teacher).
    - Students were actively engaged and had fun.
    - An atmosphere of discovery-based learning was created and maintained.
    - You made frequent use of the Glossary words from this and previous chapters and provided positive reinforcement to students using these words.
    - You were satisfied with how well the class went.
    - Your learned some new things about your students and/or yourself.
2. Assessment of student performance.
    - All students were engaged; many of them contributed in the whole-class brainstorming and/or discussion activities.
    - All students wrote in their journals.

Extensions and Follow-up

This lesson covers the idea of effective procedures and makes use of personal procedures to help illustrate effective procedures. Procedural thinking is thinking that leads to developing personal and effective procedures to solve problems. Have your students do daily journal writing on procedural thinking and how it might apply to the classes they are taking. This activity should extend over several days.

Notes

There are some people who claim that the idea of effective procedures is perhaps the most important intellectual idea that has been developed in the twentieth century. At one level it is a simple idea. For what problems can we write computer programs that will solve or help solve the problems? However, at deeper levels we get to questions such as "Can a machine think?" and "Will we eventually have computer systems that are smarter than people?" Secondary school students can begin to explore such difficult questions, and they can continue to work on them for the rest of their lives!

Additional Activities for Chapter 10

1. Why do we have computer programming languages? Why not just use English to tell a computer what to do? Discuss this question. If you know a programming language, make use of examples from that language to help in the discussion.

2. Can computers teach better than teachers? Write an essay that explores this question.

3. What ideas from computer programming readily transfer from learning one programming language to learning another programming language? What ideas don't readily transfer?

4. What ideas from computer programming seem to transfer to solving problems without use of a computer? Give specific, personal examples.

5. Why can't computer scientists write a program that can solve any problem posed to it, provided only that the problem is solvable?

Chapter 10 Overhead Transparency 1
Organize Your Thinking

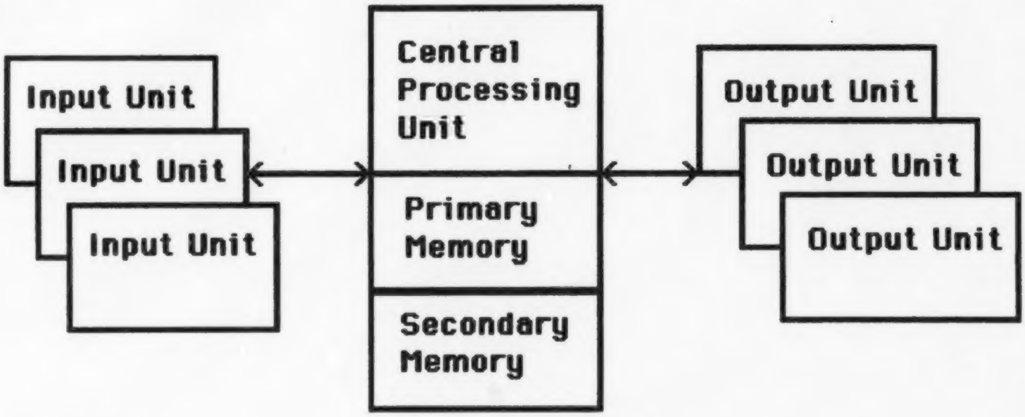
ORGANIZE YOUR THINKING

A computer system consists of hardware and software. Hardware is physical machinery. Software is computer programs.

The computer field is changing rapidly. Each year, computer systems improve quite a bit. Both the hardware and the software get better.

To use a computer, you must "communicate" with the machine. You must tell it what to do. Modern computers are much easier to use than older computers because it is easier to tell them what to do. Rapid progress in continuing in this area.

Chapter 10 Overhead Transparency 2
Computer Hardware System


Input Unit
Input Unit
Input Unit
Central Processing Unit
Primary Memory
Secondary Memory
Output Unit
Output Unit
Output Unit

Each of the hardware components of a computer system is being substantially improved over a period of a few years.

Chapter 10 Overhead Transparency 3
Effective Procedure

Effective procedure: A detailed step-by-step set of instructions with the following characteristics:

1. **The set of instructions is designed to accomplish a specified task (solve or help solve a specified type of problem).**
2. **The set of instructions can be mechanically interpreted and carried out by a computer (or by a computerized machine, such as a robot).**

Some effective procedures that are often used:

1. **Sort a list into alphabetical order.**
2. **Sort a list into numerical order.**
3. **Search through a list to see if it contains a particular item.**
4.
5.
6.

Chapter 10 Overhead Transparency 4
Personal Procedure

A procedure you carry out routinely—almost without thinking—to help you solve a problem. Examples:

1. **Tying a bow in your shoelace.**

2.

3.

4.

5.

6.

7.

Chapter 10 Overhead Transparency 5
Errors in Using Personal Procedures

1. If I make a mistake in tying my shoe, I can see that I have a knot or that the shoe is not tied.

2.

3.

4.

5.

6.

Chapter 10 Overhead Transparency 6
Chapter 10 Summary

CHAPTER 10 SUMMARY

Each year sees continued rapid progress in computer hardware and software. This progress is occurring in three areas:

1. Development of hardware that is faster, more reliable, and cheaper.

2. Development of software that is easier to learn how to use and easier to use.

3. Development of packages of application software that can solve or help solve the problems in a particular discipline.

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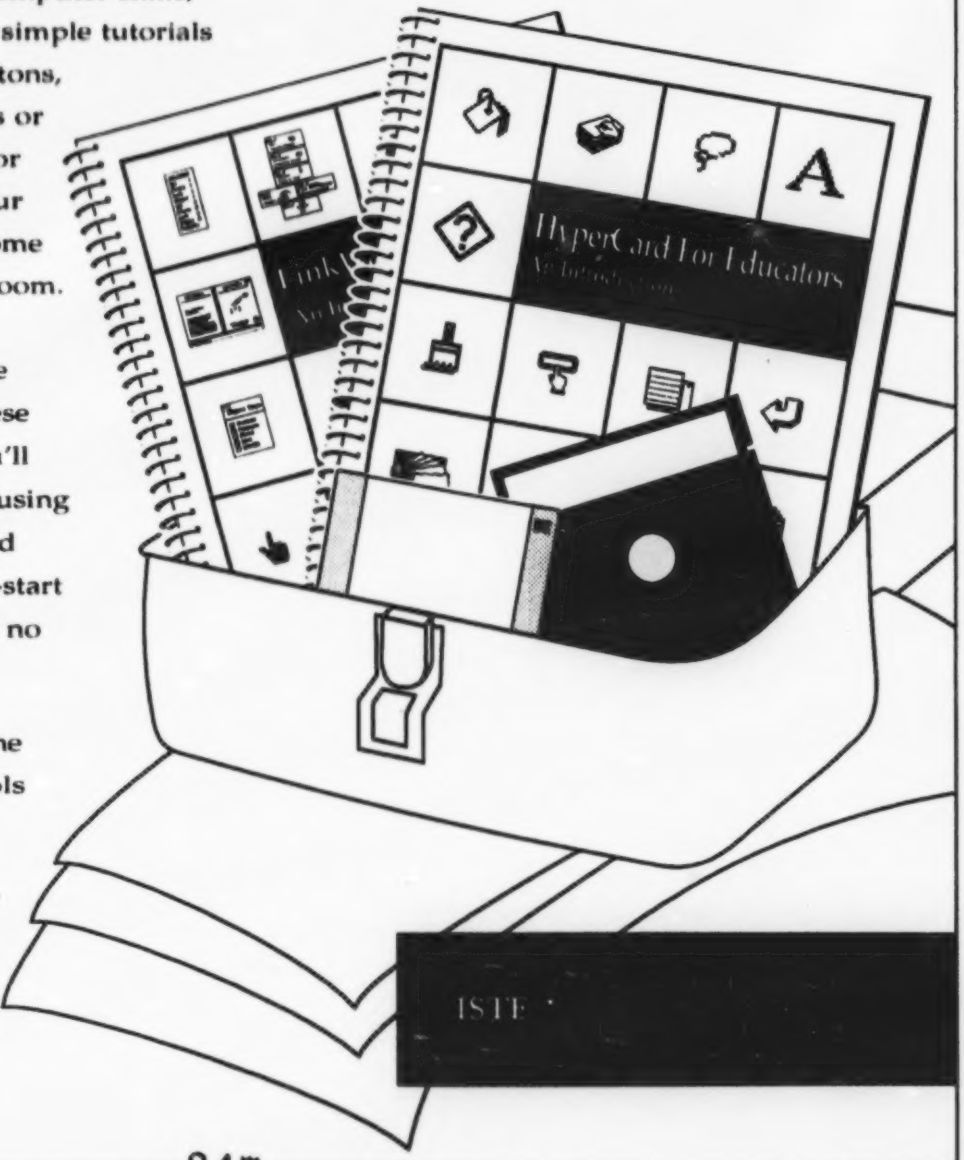

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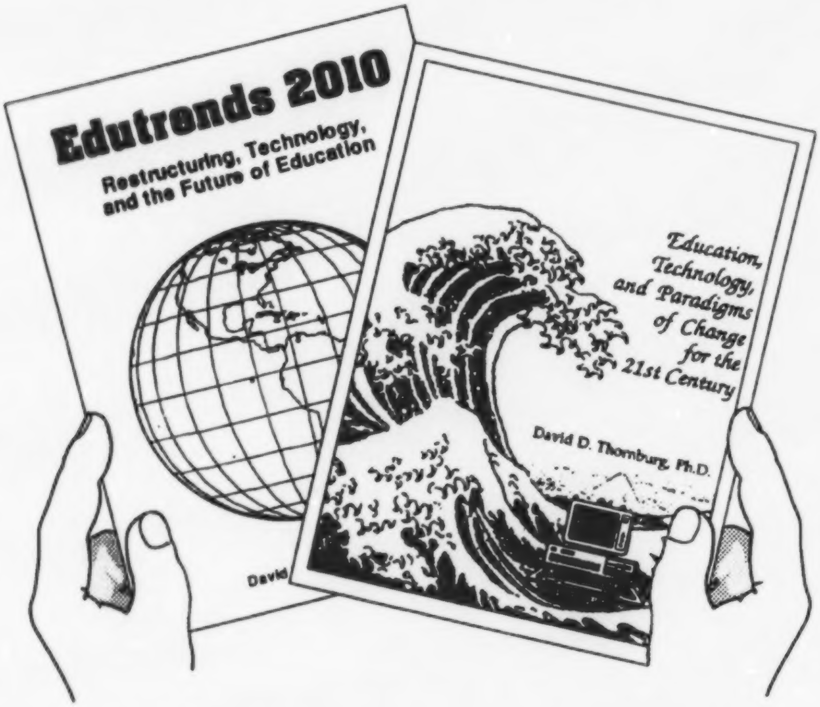
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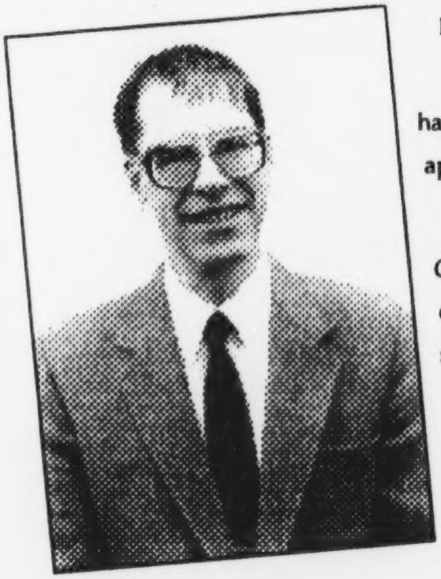

ISTE Executive Officer Dave Moursund is dedicated to improving education.

Since he first began working with computers in education in 1963, Dave has constantly sought to improve education at all levels through the use of appropriate computer-related technology.

As a continuing part of this effort, Dave's newest book—*The Technology Coordinator*—discusses the goals of education and how teachers and teachers of teachers can join in the enormous change process facing today's schools.

This book was written for educators who want to play a leadership role in the instructional use of technology. Dave uses interviews with technology coordinators to illustrate the needs, roles, and qualifications needed to accomplish the goals of educational technology.

In recent years, Dave has focused much of his writing efforts on problem solving and on staff development. Some of Dave's other books also available from ISTE include *Problem-Solving Models for Computer Literacy, LogoWriter for Educators: A Problem Solving Approach, Logo PLUS for Educators: A Problem Solving Approach* (co-authored with Sharon Yoder), and *Effective Inservice for Integrating Computer-as-Tool into the Curriculum.*

"Our educational system is not nearly as good as it could be," says Dave. "We know that computer-related technology can make substantial contributions to improving both the content of the curriculum and the instructional delivery system. Such technology can empower students and teachers."

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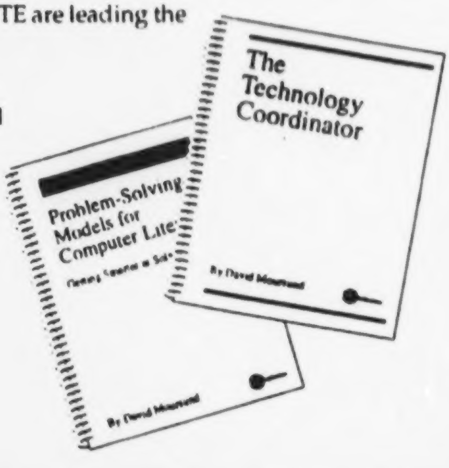
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